Agriculture and Dairy in Eastern Europe after Transition

focused on Poland and Hungary

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Dit onderzoek is uitgevoerd binnen de onderzoeksschool Mansholt Graduate School of Social Sciences

Agriculture and Dairy in Eastern Europe after Transition focused on Poland and Hungary

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Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
prof.dr. M.J. Kropff,
in het openbaar te verdedigen
op vrijdag 9 februari 2007
des namiddags om half twee in de Aula.

Agriculture and Dairy in Eastern Europe after Transition focused on Poland and Hungary
Ph.D. Thesis, Wageningen University (2007),
With references – With summaries in English and Dutch.
ISBN 90-8504-590-8

Subject headings: CEECs, Hungary, Poland, dairy, production economics, Markov chain, and maximum entropy econometrics.

Abstract

Tonini, A., 2007. Agriculture and dairy in Eastern Europe after transition focused on Poland and Hungary. PhD Thesis, Wageningen University, The Netherlands.

This thesis analyzes the transition of an economic sector, from a socialist system to a market economy. By using microeconomic theory, available data and elaborated econometric methods, the thesis shows that this joint effort leads to sensible results. The first part deals with sectoral economic analysis for Central Eastern European Countries (CEECs) that signed agreement for the European Union (EU) accession in 1998. The second part is focused on two countries (Poland and Hungary) and the dairy sector. Analytical methods used are: stochastic frontier, distance function, profit function, and Markov chain. The data were sourced from Eurostat, FAO, OECD and national statistical offices. The observations related to the former socialist regime were discarded removing the possibility of relying on traditional estimation techniques. Easier applicability was exchanged for more relevance. Maximum Entropy, which is a non-conventional estimation technique suitable for dealing with "ill-posed", and/or "ill-conditioned" problems, was largely used. By reconciling sample information and non-sample information in a rigorous and transparent manner this thesis sought to make the best estimates possible from the available information. Results of the first part indicate that despite the decrease in output, total factor productivity growth rates were positive across all CEECs analysed during the post socialist period. Countries which during the socialist regime were characterised by large-scale operators were more technologically efficient compared with the other countries analysed. This supports the view that large-scale farming performs better than small-scale farming in the period following transition when there were missing markets and uncertain economic conditions. The agricultural output mix was largely influenced by transition. Results indicate that it is going to be difficult to increase chicken meat getting rid of the other agricultural products. Adjustment costs were greater and increasing over time for Hungary as compared to Poland. The model detected overspecialization for sugar beet production. In the second half of the 1990s the degree of complementarity and substitutability is increased.

Second the thesis analyzed the primary dairy production of Hungary and Poland modelling their dairy and beef supplies as well as their dairy farm structures. The developed supply model showed an original and empirically based way for satisfying theoretical consistency as well as plausibility. Final supply elasticities estimates were not so different from those found for EU-15 countries in the pre-quota period. This confirms that dairy operations rely on a similar production technology and that the calibrated elasticities used in the literature are not far from reality. The dairy farm size projections showed that the number of dairy farms will continue to decline in the coming decade, although with an increase in the number of farms of medium and large size. The exit from the sector of the subsistence dairy farms is predicted to proceed more slowly in Poland than in Hungary. The findings suggest a convergence to a dairy farm structure similar to the one encountered in the former EU-15 members with a predominance of medium size farms. The degree of convergence will largely depend on the mediating role of a well-defined and functioning land market.

Keywords: CEECs, Hungary, Poland, dairy, micro economic theory, efficiency, productivity, allocative efficiency, stochastic frontier, profit function, Markov chain, and maximum entropy econometrics.

Preface and acknowledgements

I would have never been able to start, develop, and complete this research without the support of several people. I am therefore glad to have the chance to express my gratitude to all the people who fruitfully helped, encouraged, and supported me during my PhD research.

I would like to thank Prof. Arie Oskam, who welcomed me at the Agricultural Economics and Rural Policy Group of Wageningen University. He has made possible the start of my PhD program at the Mansholt Graduate School and he certainly helped me a lot acting as a good companion in all my PhD steps instilling me at the same time the art of diplomacy.

I am particularly indebted to my daily supervisor, Dr. Roel Jongeneel, for his critical guidance, support and inspiration, ad for never letting me down during the hard moments of doing research. He certainly deserves all of the credit for teaching me how applied economic research can be carried out with dedication and rigor, but especially with great enthusiasm.

I would also like to thank Prof. Daniele Rama for encouraging me to go to Wageningen University to carry my PhD and for his support over many years.

I have really appreciated the rewarding experience at the Agricultural Economics and Rural Policy Group of Wageningen University particularly for the numerous fruitful discussions and meetings. In particular I would like to thank Dr. Alison Burrell, Dr. Koos Gardebroek, and Dr. Jack Peerlings who helped me in several occasions and for the interesting conversations we had. I am especially grateful to Wilbert Houweling who helped me in solving computer related problems as well as for his friendly attitude. I would like to thank Dineke and Karen for their kind secretarial assistance. Another person who also deserves special credit is Daan Ooms, who shared most of his time with me as a nice officemate and providing insightful discussion about econometrics and life.

I would like to acknowledge the help received by Dr. Pierre van Mouche for his mathematical advice, Dr. Timo Kuosmanen for his advice on efficiency analysis and Dr. Joy Burrough for her advice on my English.

Thanks to the internet and conferences, I could approach several researchers who helped me in my understanding throughout my research. Particular thanks go to Francisco André, George Battese, Tim Coelli, Finn Forsund, Harold Fried, Amos Golan, Thomas Heckelei, George Judge, Erwin Kalvelagen, Sudhanshu Kumar Mishra, Anit Mukherjee, Quirino Paris, Catherine Morrison Paul, Dodla Sai Prasa Rao, Spiro Stefanou, and Arnold Zellner.

Finally, thanks to my parents who helped and supported me for all the time I spent abroad.

Axel Tonini

Wageningen, October, 2006

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CHAPTER 1

General introduction

1.1 Background

This PhD thesis is divided in two parts. The first part deals with sectoral economic analysis for Central Eastern European Countries (CEECs) that signed agreement for the European Union (EU) accession in 1998. In the second part, the thesis analyzes the primary dairy sector for two of the most important dairy producers among the CEECs which joined the EU in 2004: Hungary and Poland. At the beginning of the 1990s, most Eastern European countries embarked on political reform: the so-called transition from a centrally planned economy to a market-oriented economy. The transition reform has been well documented in the literature: for an overview of the reform in the agricultural sector see Rozelle and Swinnen (2004) and Swinnen and Mathijs (1997).

In the early 1990s, much emphasis in the literature was given to the decline in output after reform; much less attention was paid to trends in agricultural performance (e.g. productivity growth). The contraction in output was often looked at and described as a negative outcome of the reform. However, in most circumstances the fall in agricultural output was a natural consequence of relative price changes and not necessarily a sign of bad performance. The magnitude of the fall in output roughly reflects the extent to which agriculture was subsidised during the former socialist regime. Looking solely at the fall in output is not sufficient to prove that transition reform has had a negative impact on agriculture.

After the dismantling of the socialist regime there were two views on farm viability (Petrick and Weingarten (2004:9)). The first perspective argued that most of the collective structures derived from the planned system would have been unable to face the new market-oriented rules because of their outdated structure and managerial organisation. The second perspective maintained that large-scale farming would have been better able to face globalised competition.

During transition, price liberalisation required the removal of government subsidies on production and consumption. This led to a worsening in the terms of trade for agricultural products. For example, the terms of trade decreased by 30 per cent in Hungary and 60 per cent in Poland, increasing the marginal costs of production (Liefert and Swinnen (2002:8)). Although there is wide knowledge on how the reform affected the different agricultural commodities, much less is known about how the different agrarian structures in the CEECs were able to cope with output adjustments due to changes in relative prices (i.e. allocative efficiency). To shed light on this it is useful to examine two countries with contrasting farm structure: Hungary (which has both large-scale and small-scale farms) and Poland (which has many small-scale farms). These countries were the focus of the research described in this thesis.

The remainder of this section deals with the dairy sectors of the enlarged EU. Ten new member states (NMS) joined the EU on May 2004. Eight of these were from Central Eastern Europe[1]. The EU-25 is the world's largest producer of cow's milk, with Hungary and Poland ranking respectively fifteenth and fourth in the EU-25 In 2005, Hungary's production of cow's milk was 2.0 million tonnes and Poland's was 12.4 million tonnes, representing respectively about 1.4 and 8.7 per cent of total EU-25 cow milk production (FAO (2006)). Though dairy farming is one of the most profitable sectors of agriculture,[2] it is a challenging sector to analyse, due to the presence of different policy instruments which affect the final market equilibrium.

As a consequence of accession, the NMS had to absorb the common agricultural policy (CAP) framework and comply with the *acquis communautaire*. Some of the most important changes in the European dairy sector were instigated in 2003 by the Luxembourg reform, which required a substantial reduction in the intervention price support for butter (-25 percent) and skimmed milk powder (-15 percent), the retention of the milk quota system (until 2014), and payments decoupled from production in order to partly compensate dairy farmers for the decline in price support. In addition, there were several problems in extending the CAP to the NMS, of which the most controversial were the attribution and base for direct income payments and the milk quota allocation. Given the above, there is much interest in empirical research characterising the dairy supply of CEECs in order to analyse different policy options. This is the more urgent since further reform of the CAP will be considered in 2008 (Fischer Boel (2006)). Up to now a number of models analysing several policy scenarios for the NMS considering the dairy sector alone or in conjunction with other agricultural sectors have been presented in the literature (Swenning (1999), Wahl, Weber and Frohberg (2000), Mergos (2002), Jensen and Frandsen (2003), FAPRI (2004), Ledebur and Manegold (2004), Banse and Grethe (2005), Grethe and Weber (2005), among others). Most of the models are static partial equilibrium models. Thus they do not directly take into account for the dynamic adjustments in dairy production and they are calibrated on guessed parameters,

[1] Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia.
[2] In the European Union (EU) in the mid-1990s, the family farm income per unit of unpaid labour in specialist dairy farms was EUR 25.5 thousand, which is higher than the EUR 15 thousand average for all types of farm (Burrell (2000: 314)).

therewith loosing the specificity of CEECs. Moreover, there is no check at all whether the combination of calibrated parameters generates a model that is able to predict the sector's adjustments due to reform. One of the aims of this thesis was therefore to develop an empirical dairy and beef supply model for Hungary and Poland taking into account the structural break in the policy regime and the associated data limitations.

One of the most important elements during transition was related to the restructuring of agriculture (Rozelle and Swinnen (2004), Swinnen and Mathijs (1997)). The structure of dairy farming in CEECs has had to adapt to the newly reformed economy and at the same time has followed several patterns common within the former EU-15 members. In order for the farm structure to adapt to the reformed system, legal property rights had to be defined and agricultural assets (i.e. land and other assets) had to be redistributed to private owners. Patterns in common with the former EU-15 members are the scaling-up of dairy production, the reduction of the number of dairy farms and the increase in herd size per farm. In addition, the national number of dairy cows is decreasing and milk yields are improving. In the last five years in Hungary and Poland, the number of dairy cows has declined by 13.0 and 9.4 per cent respectively and milk yields have improved by 7.3 and 15.1 per cent. Policy makers and the dairy industry are very interested in how the dairy farm size structure of the CEECs which recently joined the EU will evolve. It is unclear whether in the short run CEECs will be able to adapt and adjust their dairy farm structures to the one which characterizes Europe with many medium size farms. The role of subsistence farming in dairy production is also of great concern. Subsistence farming produces some 25 per cent of the total cow's milk production in Poland. It is not clear to what extent these farms will persist or whether they will leave the sector.

1.2 Research objectives and questions

This thesis deals with the transformation of agriculture and its dairy sector for the CEECs with particular attention for Hungary and Poland. The transformation was a natural consequence of the new market oriented rules introduced by the transition reform, as well as of the EU dairy policies brought by the EU enlargement. The first part of the thesis analyses the agricultural sector of several CEECs whereas the second part of the thesis analyses the dairy sectors of Hungary and Poland. The research objectives are twofold. First, the focus is on analysing the country-level performances of several CEECs during the post-socialist period. This will be done by estimating several productivity indicators such as: country level technical efficiency scores, total factor productivity (TFP) estimates, marginal rates of transformation and Morishima elasticities. The research questions to be answered in the first part of the thesis are:

1. Is the collapse of agricultural output a good indicator of economic performance for the ten CEECs which applied in 1998 for EU accession?
2. Do countries with large-scale farming perform better than countries with small-scale farming?
3. How do the transition-induced adjustments to the mix of agricultural outputs differ between Hungary and Poland?

Second, the focus is on analysing the primary dairy production of Hungary and Poland, particularly their supplies and farm structures. The thesis sets out to model the dairy and beef sector for Hungary and Poland by relying on an enriched estimation procedure which allows external sources of information to be incorporated into sample data. By so doing, the aim is to provide an empirical framework which circumvents some of the data problems frequently encountered with CEECs. In addition empirical evidence is given on the acceptability of the calibrated elasticities used for the dairy partial equilibrium models found in the literature. Another objective was to analyse the farm structure by introducing information on farm structure and mobility during the estimation procedure. Thus the research questions to be answered in the second part of the thesis are:

4. How is it possible to model the post-socialist dairy supply for Hungary and Poland in the face of severe data limitations and institutional hiatuses?
5. Are the calibrated elasticities used in the dairy partial equilibrium models found in the literature empirically acceptable?
6. How has the dairy farm structure of Hungary and Poland changed in the post-socialist period?
7. Which dairy farms are likely to survive in the future?

1.3 Data used in the thesis

This section briefly describes the problems encountered in gathering statistical information and then explains what kind of information was used. Importance is given to the general principles followed when addressing the research questions that were set out in the previous section.

The initial research proposal for this thesis anticipated that the data used would be repeated observations over dairy farms, collected over a number of periods (i.e. panel data). The availability of panel data at farm level allows more refined and more realistic models to be specified and estimated than would be possible using a single cross-section or a single time series (Verbeek (2004: 341)). After beginning the research and contacting local statistical offices, national agricultural economics institutes and European sources, however, it was found that micro-level data on the dairy farms could not be collated, because such data were unavailable for scientific research. As a result, all the research undertaken was based on aggregate country-level data. The data were sourced from Eurostat, FAO, OECD and national statistical offices. More details on the sample data used in each empirical analysis will be found in subsequent chapters.

The problem of the quality of economic data has been topical for many years and the debate is still ongoing. Given that poor data are better than no data, it can be concluded that the best possible data should be used for an empirical study, even though their quality is poor. The data for CEECs are even more problematical than normal (Blangiewicz, Bolt and Charemza (1993), Hallam (1998)). In some circumstances, the relevant quantitative information for the planned modelling exercise is simply not available. In other circumstances, even though the data are available, their definition may have changed over time or their availability is limited to only few data points. In all these cases the researcher is faced with several choices on how to make the most efficient use of the available information.

One of the most important choices that had to be made was therefore whether to rely on data predating the transition reform. During the transition from a socialist system to a market economy, not only has the system that the data are supposed to describe changed, but so has the way the data were collected (Hallam (1998)). In this thesis, the principle of using the best possible data in analysing the economic system under scrutiny was followed, by discarding observations related to the former socialist regime. This was not a trivial decision, since it removed the possibility of relying on traditional estimation techniques. In most of the following chapters, the problems it was attempted to address were "ill-behaved" in the sense that the number of unknowns to be recovered frequently exceeded the number of available data points.

In order to handle the "ill-behaved" nature of the problems that were set out, much use was made of non-sample information (NSI) (Judge, Griffiths, Hill, Lütkepohl and Lee (1985), Toutenburg (1982)). NSI is a broad term encompassing all the available information that is external to the data of the sample under analysis. More precisely, NSI can be conceptualised by adding several restrictions to parameters, in order to increase the efficiency of the inference procedure. There are several possibilities of incorporating NSI; they will be discussed in depth in later chapters. The nature of the NSI may be known from economic theory and/or because there is prior knowledge about certain established empirical relationships. Whenever possible, use was made of information from previous studies reported in the literature.

1.4 General approach, estimation and outline of the thesis

This section treats the general methodological approach and the main contents of Chapters 2–5, each of which is a published or submitted paper. Inevitably, such a thesis has some overlap between chapters.

This thesis is largely based on concepts of agricultural production economics that rest on microeconomic principles. The theoretical notions come from neoclassical theory and statistical inference, which provides the main theoretical basis for the empirical analysis done in this research. The approaches used are: stochastic production function frontier (Coelli, Prasada Rao, O'Donnell and Battese (2005), Kumbhakar and Lovell (2003)), distance function (Färe and Primont (1995)), profit function (Chambers (1988), Mass-Colell, Whinston and Green (1995)) and Markov chain (Lee, Judge and Zellner (1970)).

The most recurrent estimation procedure used is based on the Maximum Entropy (ME) formalism (Golan, Judge and Miller (1996), Mittelhammer, Judge and Miller (2000)). The ME algorithm is suitable when problems are "ill-posed", and/or "ill-conditioned" (Paris and Howitt (1998)). The entropy function is based on the entropy distribution of probabilities over a set of outcomes. By connecting the entropy function with several data consistency constraints and normalisation-additivity requirements, the problem is transformed into an inference procedure that seeks to make the best predictions possible from the information that is available. In this way, ME allows us to efficiently exploit not only the primary sample data, but also valuable information about all the different possible outcomes that are external to sample data.

Chapter 2 addresses the first two research questions and provides a description of the effects of transition and the consequent agricultural adjustments. It estimates a stochastic production function frontier for the period 1993–2002 based on country-level panel data and it provides first empirical estimates of technical efficiency scores for the ten CEECs that signed agreements in 1998 for accession to the EU. The chapter also derives TFP growth estimates. The approaches used in the chapter are based on stochastic production frontier analysis and Malmquist index, both of which are suitable techniques when there is no information on input prices and/or their variability is not sufficient to carry reliable inference procedures.

Chapter 3 addresses the third research question, focusing on a case study for Hungary and Poland. It estimates an output distance function incorporating NSI in the estimation, exploiting for the first time a mild revenue maximisation condition. The distance function approach, which comes from the duality theory of production, allows us to model multi-output production technology without the need to impose a strong behavioural assumption. The paper provides insights into the output substitutability patterns during the post-socialist period. In addition it makes it possible to examine potential allocative inefficiencies consequent to changes in relative prices.

Chapter 4 addresses the fourth research question, providing an innovative empirical framework that is able to recover dairy supply estimates in a context where the sample information is limited to few data points. The model takes into account stock adjustment equations for the quasi-fixed inputs, in addition to the dairy and beef supplies. In so doing, the model captures medium-run adjustment dynamics which are ignored in the most diffused comparative static analysis based on a partial equilibrium model calibrated on guessed parameters.

Chapter 5 addresses the final two research questions of this thesis. First the underlying dynamics for the dairy farm structures of Hungary and Poland during the post-socialist period are estimated. Second on the basis of the modelled dynamics, several projections are made on the likely dairy farm size configurations for the coming decade. This paper makes use of a generalised cross-entropy approach applied to a Markov chain approach. In this way, some of the data limitations are solved by incorporating during estimation prior knowledge about farm mobility and farm dynamics.

Chapter 6 provides a discussion of several limitations encountered in the data, it discusses the main methods used, it delivers an overview/synthesis of the results, it elaborates elements for further research and it closes with a list of main conclusions.

CHAPTER 2

Is the collapse of agricultural output in the CEECs a good indicator of economic performance? A total factor productivity analysis

Abstract

This paper analyzes total factor productivity (TFP) growth in agriculture for the ten Central and East European countries (CEECs) that began formal negotiations for EU accession in September 1998. A panel data set is constructed consisting of pooled time series data for the ten CEECs from 1993 to 2002, and is used to estimate a time-varying stochastic production frontier. A Malmquist index of TFP growth is estimated and decomposed into efficiency change and technical change. The results show that despite the fall in output, TFP growth rates were positive for all ten CEECs. This suggests that the collapse of agricultural output in the CEECs is not necessarily a good indicator of agricultural performance. An analysis that only focuses on output decline provides a partial and misleading interpretation of the success of agricultural reforms. Also, estimates of technical efficiency confirm the hypothesis that large-scale farming performs better than small-scale farming when markets are missing and economic conditions are uncertain.

Tonini, A., and R. Jongeneel. 2006. "Is the collapse of agricultural output in the CEECs a good indicator of economic performance? A total factor productivity analysis." (Adapted)/From EASTERN EUROPEAN ECONOMICS, vol. 44, no. 4 (July-August 2006): 32-59.

2.1 Introduction

The causes of output decline in transition economies have been studied rather extensively (see, e.g., Blanchard (1998), Macours and Swinnen (2000), Swinnen (2002), Rozelle and Swinnen (2004)). However, if not complemented by other indicators, analysis of the collapse of agricultural output may provide misleading conclusions about agricultural performance. The decline in output has been an inevitable consequence of worsening terms of trade following price liberalization, subsidy cuts, privatization, and farm restructuring (Macours and Swinnen (2000: 174)). An alternative assessment of the sector's performance could rely on partial productivity indicators. However, during transition, the productivity of intermediate inputs, such as labour and land, was asymmetrically affected by changes in relative prices.

The best measure of the performance of transition economies is total factor productivity (TFP) growth, defined as the "weighted average of growth in productivity of each individual input used in production, where the weight of each input equals its share in the total value of production" (Liefert and Swinnen (2002: 23)). The TFP index has been formally proved to be adequate for comparing units with nonidentical production functions, because differences in outputs are explained by differences in technology and efficiency (Caves, Christensen and Diewert (1982: 1394)). Although all Central and East European countries (CEECs) underwent reform away from centrally planned regimes and toward free-market economies, the countries differ in their specific characteristics, such as land privatization policies and farm structure.

Several studies measure agricultural performance in transition economies. Macours and Swinnen (2000) use a parametric approach to measure TFP growth for eight CEECs—Albania, Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, and Slovenia—for the crop sector between 1989 and 1995, a particular unstable economic period. Swinnen and Vranken (2005) apply a data envelopment analysis approach to efficiency scores of crop farms for Albania, Bulgaria, Czech Republic, Hungary, and Slovakia from 1997 to 2001. Focusing on the former Soviet Union (FSU) republics, Lerman, Kislev, Kriss and Biton (2003) rely on a parametric approach. None of the previous studies have analyzed at once all ten CEECs that applied for European Union accession. It is difficult to compare the few available studies in the literature, because they differ in the number of countries considered, the time horizon, and the sample data used for estimation.

The present paper focuses on analyzing TFP growth of ten CEECs—Bulgaria, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia—that began reforms at a similar time, and started formal negotiations for EU accession in September 1998. The question in the title of the paper, whether the collapse of agricultural output in the CEECs is a good indicator of their economic performance, will be answered as follows. First, the causes of the decline in agricultural output are described, and then the adjustment process underlying the reform period is elaborated by referring to partial productivity indicators. Second, by estimating TFP growth for the ten CEECs, it is showed that it is short-sighted to use the collapse of agricultural output and partial productivity measures as indicators of agricultural performance. TFP growth is also decomposed into efficiency change (EC) and technical change (TC) by relying on a time-varying stochastic frontier. Finally, the following hypothesis are tested: CEECs that did not dismantle their large-scale farming structure from the Soviet period (e.g., Czech Republic, Hungary, and Slovakia), but instead adapted to the new regime, tend to have more efficient agricultural sectors than do countries that shifted into small-scale farming (e.g., Baltic region).

2.2 The effects of transition and the economics of "adjustment"

This section describes the main causes of the substantial decline in agricultural output and elaborates on the adjustments underlying the transition[3] process. The degree of reform success varied greatly among countries due to country-specific differences. Table 2.1 contains some of the main economic indicators. Agriculture represents a large share of the national gross domestic products (GDP), especially for Bulgaria, Romania, Lithuania, and Poland. In these countries, agriculture also accounts for a large share of total employment. Compared to other countries, Poland has a relatively high labour-to-land ratio, and at the same time, has a very high unemployment rate. Estonia and Hungary have the lowest and highest percentage of utilized agricultural area, respectively. Due to escalating inflation generated by liberalizing domestic prices, consumer prices increased. Consequently consumer purchasing power and real income decreased, resulting in a contraction of domestic demand for foodstuff. In Poland, food prices increased between 1988 and 1990 by more than 500 percent Swinnen (2002:

[3] In Colombatto (2002: 61) transition is defined as "the period of time it takes for new institutions and organizations to be introduced and upheld, for a gents to learn how to operate according to a reformed system of property rights and adjust hitherto virtually unknown rules of the game".

484)). Many countries also faced a drop in net exports because of unfavourable international prices and the FSU crisis.

Table 2.1 Selected agricultural and economic indicators for ten CEECs, 2000

Country	Share of agriculture in GDP (percent)	Share of agriculture in total employment (percent)	Labour-land ratio (pers./ha)	Utilized Agr. Area (percent of total area)	Inflation rate (percent)	Unemploy ment (percent)
Bulgaria	16.0	26.2	0.09	50.3	10.6	16.9
Czech Rep.	3.4	4.5	0.15	54.3	4.7	8.7
Estonia	4.7	7.6	0.09	19.7	4.5	12.5
Hungary	3.9	6.0	0.11	62.9	9.2*	6.3
Latvia	4.0	13.5	0.09	38.5	2.5	13.7
Lithuania	6.9	19.6	0.08	53.4	1.3	16.4
Poland	2.9	18.8	0.31	58.3	10.2	16.4
Romania	11.4	42.8	0.19	62.1	45.7	7.1
Slovakia.	4.5	6.7	0.18	49.8	12.0	18.7
Slovenia	2.9	9.9	0.13	24.2	8.4*	6.6
EU-15	2.0	4.3	0.09	40.6	1.9	8.1

* 2001 value. Labour-land ratio is our estimate.

Source: EC (2002), WIIW (2003), FAO (2004), and Eurostat (2005).

The disruption of the centrally planned regimes in the early 1990s initiated a process towards market liberalization, which entailed a shift from agricultural assets being controlled by the state to being allocated by market mechanisms. This induced a remarkable decline in agricultural output, caused by price liberalization, subsidy cuts, a decline in consumer purchasing power, and a decline in exports. Various author have described the causes of the output decline in transition economies (Blanchard (1998), Macours and Swinnen (2000), Swinnen (2002), Rozelle and Swinnen (2004)). Most of the CEECs are still recovering, and have not yet reached pretransition output levels. This is illustrated by the agricultural production index number[4] (PIN) in Table 2.2.

The Baltic countries, together with the Slovakia, experienced the largest contraction in production (see Table 2.2), mainly due to the negative effect of transition on capital-intensive agricultural productions (i.e., the livestock sector), which play a relatively important role in

[4] The FAO PIN is calculated by the Laspeyres formula, in which net production quantities of each commodity are weighted by the base-period average international commodity prices and summed for each year. International commodity prices are used to avoid the use of exchange rates for obtaining continental and world aggregates, and also to improve and facilitate international comparative analysis of productivity at national levels.

these countries[5]. Due to bad weather conditions, agricultural production decreased at the end of the 1990s in many CEECs, conditions possibly exacerbated by unfavourable price trends in international markets WIIW (2001).

Table 2.2 Growth of agricultural production index number (PIN) for ten CEECs (1993=100)

Country	PIN in 1997	PIN in 2002	Year with lowest PIN	PIN in year of lowest PIN
Bulgaria	101	102	1996	90
Czech Rep.	79	80	2003	72
Estonia	65	61	2000/01	60
Hungary	113	109	1993	100
Latvia	64	55	2000/01	50
Lithuania	83	74	2001	69
Poland	92	93	1994	85
Romania	105	90	2000	79
Slovakia	100	89	2000	77
Slovenia	113	121	1993	100

Source: Authors' calculations, based on FAO (2004).

Price liberalization and subsidy cuts significantly worsened terms of trade for many CEECs. Estonia was one of the first FSU countries to introduce price liberalization between 1990 and 1992. Rozelle and Swinnen (2004: 420) show that in the first five years of transition, the output-to-input price ratio in agriculture declined by 30 per cent in Hungary, 50 percent in Czech Republic, and about 70 per cent in Slovakia, Poland, and some of the Baltic states. As terms of trade worsened, input use decreased, penalizing agricultural production. Table 2.3 indicates the changes in inputs for the ten CEECs.

The adjustment in input use following transition varies greatly between countries. On average, between 1993 and 2002, labour input (measured as economically active population in agriculture) and livestock capital in the ten CEECs declined by 32 and 31 percent, respectively. The largest contraction in livestock was in Latvia. The largest contraction in labour was in Slovenia, though in an exception to the rule, livestock did not show remarkable decline there. Fertilizer use increased in the majority of the ten CEECs, especially in Lithuania, where poor-quality soils prevail. Machinery stocks rose significantly in Slovenia, Lithuania, and Hungary. As Table 2.3 indicates, land input has not varied much over time (see also Lerman, Kislev, Kriss and Biton (2003: 1012), Macours and Swinnen (2000: 174)).

[5] For example, in Estonia, animal products represented 58.6 percent of the average value of agricultural production between 1998 and 1999.

Table 2.3 Growth of input use index for agriculture for ten CEECs (1993=100)

Country	Labour		Livestock		Fertilizers		Machineries		Land	
	1997	2002	1997	2002	1997	2002	1997	2002	1997	2002
Bulgaria	75	53	62	52	98	81	107	94	104	83
Czech Rep.	90	78	79	65	103	120	105	106	98	97
Estonia	84	72	55	46	43	42	105	109	99	55*
Hungary	87	73	86	79	146	171	99	119	101	97
Latvia	83	70	46	37	37	52	102	102	107	109
Lithuania	82	65	65	49	158	223	113	121	98	98
Poland	93	85	95	82	133	118	101	98	98	97
Romania	83	66	87	64	52	54	98	102	100	100
Slovakia	93	83	78	56	111	129	83	71	99	97
Slovenia	67	38	96	97	136	128	123	131	87	84

* Between 1993 and 2000 the change in land use for Estonia was about -1 percent; overall change is attributable to remarkable contraction in 2001 and 2002. For a detailed definition of the variables see text.

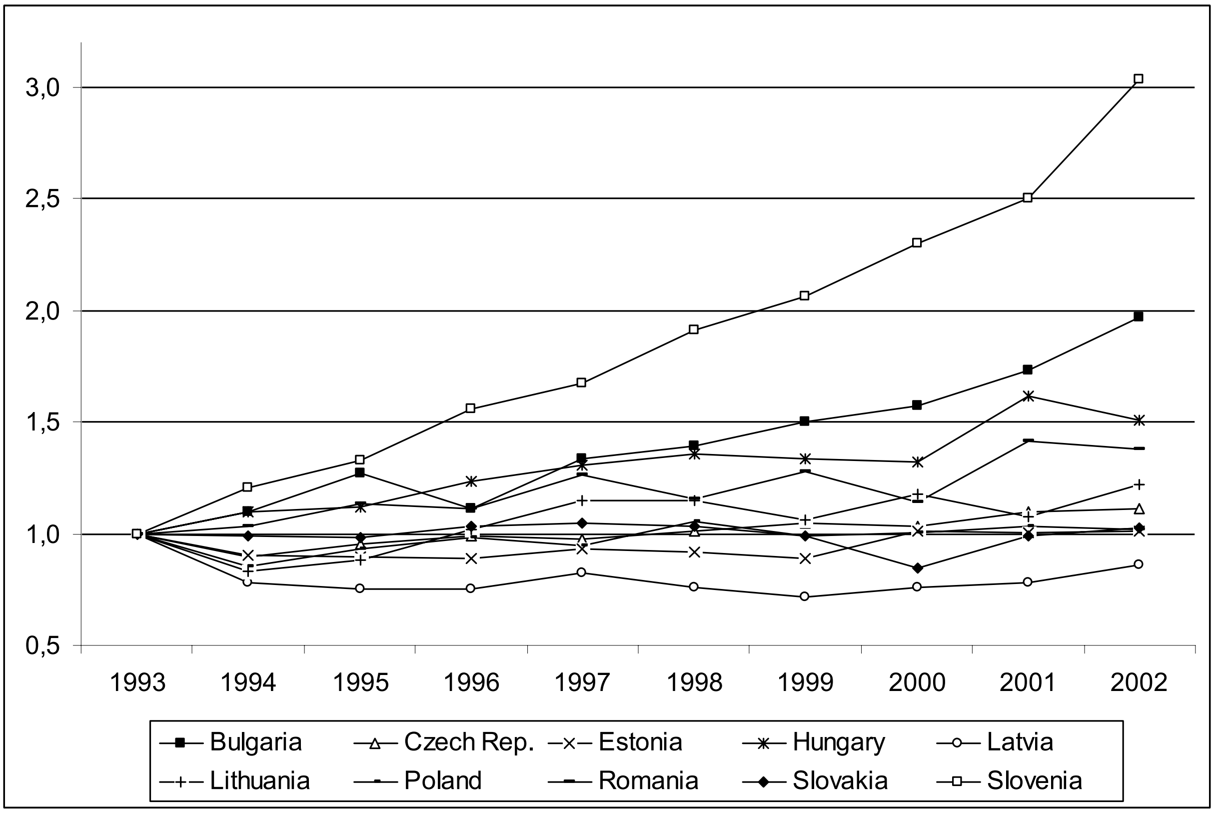
Source: Author's estimations based on FAO (2004).

Poland and Slovakia had a relatively low annual rate of decline in labour of about 2 percent, whereas the average annual rate of decline in the other countries was about 5 percent. The lower annual rate of labour decline for Poland and Slovakia is likely due to the social buffer function of agriculture[6]. In pretransition industries, labour outflow was avoided by creating "over-full employment" (Holzman (1955: 455)), facilitated by "soft budget constraints" (Kornai (1986: 3-30)). However, hidden unemployment in agriculture had a different source, as farming activities, especially for small, privately held individual farms, represented the only way of obtaining livelihood. At the same time, farming's role as a safety net constituted a bottleneck for the outflow of labour from agriculture in many CEECs, inhibiting agricultural labour productivity and the modernization of the sector. Figure 2.1 shows changes in agricultural labour productivity (APL). Despite the simultaneous contraction in agricultural output and labour input in the majority of CEECs, one can see a rise in ALP for several countries, such as Bulgaria, Hungary, Romania, and especially Slovenia.

During the collectivisation era, farmers were required to contribute their agricultural assets to the collectives. Land assets remained mostly privately owned, except for the Baltic States, where land was entirely nationalized. Nonland assets, which were originally privately owned, became property of the collectives. However, with the transition reform, all

[6] Agriculture in may CEECs represents an important household security system, acting as a " social buffer," especially when uncertainty (i.e., regime shifts, privatization) is increased by low employment opportunities in the economy (Petrick and Weingarten (2004: 3)).

agricultural assets had to be privatized. The most commonly followed methods of privatization were restitution, sale, emission of vouchers, and the starting up of small private family businesses (Brada (1996: 68-76)). According to Swinnen and Mathijs (1997: 335-342), most of the collective land was restituted to former owners at the outset of the reforms, and state land leased or sold, whereas nonland inputs were mostly redistributed. For an overview of the status of agricultural reforms in the countries considered in this analysis, see Table 2.4.



Note: Agricultural labour productivity is computed as the ratio of agricultural output to economically active person in agriculture.

Source: Author's calculation.

Figure 2.1 Agricultural labour productivity for the Ten CEECs (1993=1)

Former collective land was mainly restituted to former owners, according to historical boundaries. Although in principle, land restitution could have disrupted ownership rights and user rights significantly, it appeared to be a more successful policy than were the paper shares or certificates issued in Russia and Ukraine. A well-developed land market is a necessary condition to foster productivity: it allocates land from less efficient farmers to more efficient farmers, taking care of both efficiency improvements and adjustment in farm structure. This presumes the existence of well-defined land property rights. The Czech Republic has been one of the most advanced CEECs in land restitution. In 1994, about 80 percent of agricultural land was entirely restituted, whereas Bulgaria had restituted only about 23 percent of arable land in 1993. In Romania, thought about 93 percent of agricultural land was privately owned in 1993, only a few people had received their ownership titles; in 1996, only 50 per cent of landowners had received their titles (Swinnen and Gow (1999: 30)).

Table 2.4 Status of agricultural reform in ten CEECs

Country	Price & market liberalization	Land reform	Agro processing & input supply	Rural finance	Institutional framework	Total score
Hungary	9	9	9	8	8	8.6
Slovenia	8	9	8	8	9	8.4
Czech Rep.	9	8	8	8	8	8.2
Estonia	10	6	7	7	9	7.8
Latvia	7	9	7	7	8	7.6
Poland	9	8	7	6	8	7.6
Slovakia	7	7	8	8	7	7.4
Lithuania	7	8	7	6	7	7.0
Romania	7	7	6	6	4	6.0
Bulgaria	6	7	5	4	5	5.4

Note: 1 = Centrally Planned Economy. 10 = Completed Market Reforms.

Source: Csaki and Nash (1998: 11).

Nonland assets were only partly restituted to former owners, and mostly privatized through vouchers, which could be converted into capital shares or used to purchase nonland assets. The criteria for distributing and determining shares were the subject of debate. The general principle of nonland assets distribution was based on distributing shares to those who had contributed agricultural assets (land owners, nonland assets owners, and labour contributors) to the collectives. In Lithuania, all nonland assets were restituted to former collective members; in Hungary, 40 percent of nonland assets were restituted; and in Slovenia, only 20 percent. In Slovenia, 40 percent of the remaining shares were allocated to state funds to finance several national funds (pension, compensation, and development funds) and the other 40 percent could be privatized following a variety of methods (Swinnen and Mathijs (1997: 338-339)).

Privatization required a proper definition and attribution of legal and property rights for agricultural assets. In many places, the restitution of collective land to former members was a difficult and slow process. A number of technical factors related to the restitution process had high transaction costs, such as asset valuation, claimant valuation, and asset assignment. The restitution of physically "equivalent" and "comparable" plots was difficult, and claimants could disagree with the assigned assets. Principal-agent problems were frequent in local institutions organizing land restitution, where asymmetric information and a lack of clear legislation often favoured the old nomenclature. Privatization was dependent on having a stable government; in several CEECs, governmental change affected the privatization process (such as Bulgaria). Finally, there were several restrictions in the privatization of agricultural assets[7].

One of the most important institutional constraints in the transformation of the agricultural sector was the degree and ease of abandonment of the collective and state farm structure. It was expected that collective and state farms would be dismantled because of land privatization (i.e., redistribution). However, as mentioned above, the high transaction costs of land redistribution favoured the old collective nomenclature instead of creating new private owners. This often meant that agricultural land remained in the hands of the old collectives, particularly in countries where large-scale operators predominated Swinnen and Mathijs (1997: 365-366)).

In the decade after transition, two common findings emerged. First, a bimodal or dual farm structure appeared. On the one hand, were unspecialized small peasant family farms mainly producing for their own consumption (i.e., subsistence farming); on the other hand, were large-scale farms resulting from the decollectivization of cooperatives and state-owned farms (Brada (1996: 79), Sarris, Doucha and Mathijs (1999: 308), Tonini and Jongeneel (2002: 320-325)). Second, most of the restituted agricultural land went to large-scale operators.

Private family farms generally predominate in countries with a relatively high share of agriculture in employment (e.g., Bulgaria, Latvia, Lithuania, Poland, and Romania) and less frequently found in countries where the share of agriculture in employment is relatively low (e.g., Czech Republic, Slovakia, and Hungary). In Poland and Slovenia, land reform only

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[7] In Slovenia and Bulgaria, some property rights on agricultural assets were restored to former state and collective farms. In Baltic countries, where land in the prereform regime was entirely nationalized, farms that were than created on a usufruct basis were non entitled to sell the land (Swinnen and Mathijs (1997: 359)).

minimally affected farm structure because of the low degree of collectivisation during the centrally planned era. In Baltic states, farm restructuring entailed splitting up the collective and state structures into private units with relatively high average scale compared to other CEECs. Small- and large-scale farms coexist in Bulgaria, Estonia, and Hungary.

The establishment and modernization of farm structure faced a number of obstacles. One of the most important impediments was the lack of well-functioning credit markets. The imperfections of credit markets is well-documented, even in well developed market economies, and its imperfection is exacerbated in agriculture (Stiglitz (1993: 27-45)). The main problems in Eastern Europe derived from high inflation (see Table 2.1), unclear definition of property rights, underdeveloped land markets, low farm profitability, high transaction costs between lenders and borrowers, and assets specificity. The possibilities of borrowing money to update farm technology, or make the necessary investments to scale up farm organization, were limited. Investments are strongly related to the existence of a well-developed capital market. In a well-developed capital market, credibility and collaterals are a necessary condition for private farmers to receive bank loans. During the transformation process, farmers could not obtain loans because land titles were not entirely attributed, and therefore, land could not act as credible collateral. Bank loans were therefore difficult to obtain, even when property rights were established due to missing land markets. Because urban real estate was usually more developed than were agricultural land markets, lenders required collateral on fixed assets in urban areas. Swinnen and Gow (1999: 29-30) show that that in Bulgaria and Hungary, banks required collateral for 150 to 180 percent of the loan amount, and accepted as collateral 80 percent of the asset value in urban areas and 60 per cent in rural areas. To improve specialized credit institutions, Hungary favoured vertical integration relationships between input suppliers and output buyers, partly financed by foreign direct investment. These integrated suppliers and buyers could then act as intermediaries between banks and farmers, providing government financial packages with lower transaction costs. Foreign companies have frequently been crucial in promoting this kind of contract and providing initial liquidity to the system.

2.3 Theoretical model

2.3.1 The Malmquist index of TFP

This subsection provides the motivation for using a TFP index as a measure of productivity growth and provides some theoretical background. A TFP index measures the change in total output relative to changes in the use of all inputs. As such, it is usually preferred to more simple partial productivity measures, which may provide inappropriate results, particularly when countries experience asymmetric changes in inputs (Liefert and Swinnen (2002: 23-24)). The TFP index has been formally proved to be adequate for comparing units with nonidentical production functions, since differences in output are explained in terms of differences in efficiency and technology (Caves, Christensen and Diewert (1982: 1395-1411)).

A Malmquist index (MI) was used to measure TFP, as defined in Caves, Christensen and Diewert (1982). The MI has three main advantages over the widely used Tornqvist/Fisher Index (TI/FI) (Coelli, Prasada Rao and Battese (1998: 246)) that justify applying it to transition economies. First, the MI is less restrictive than the TI/FI because it does not assume that the units under observation are simultaneously technically and allocatively efficient. This enables the TFP measures to be decomposed into EC and TC. Second, the MI does not require imposing strong behavioural assumptions, such as profit maximization. Third, the MI does not depend on prices. For many CEECs, data on prices are scarce and, if available, are frequently affected by hyperinflation. Their use is therefore questionable. The MI has already been successfully applied to retrieve TFP indexes using either mathematical programming (see, e.g., Färe, Grosskopf, Norris and Zhang (1994)) or econometric approaches (see, e.g., Perelman (1995)).

The MI can be defined by using either an input or an output orientation. For country-level analysis, an output orientation is the proper choice (Coelli, Prasada Rao and Battese (1998: 224)). An output orientation looks for the maximal proportional expansion of an output vector, given an input resource vector[8]. The MI used in this study is based on an output distance function, which is an alternative approach to representing a production technology (Färe and Primont (1995: 7-40)).

[8] Neither an output nor an input orientation affect estimates when constant return to scale (CRS) is imposed, as required when computing MI of TFP growth.

The output-based MI of TFP measures the change in productivity between two observations by computing the ratio of the distance of each observation to a given common technology. The output-based MI of TFP index, as defined by Färe, Grosskopf, Norris and Zhang (1994: 70-71) may be written in such a way that the different components of EC and TC in the MI of TFP can be distinguished:

$$MI_0\left(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1},\boldsymbol{x}^{t},\boldsymbol{y}^{t}\right)=\frac{D_0^{t+1}\left(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1}\right)}{D_0^{t}\left(\boldsymbol{x}^{t},\boldsymbol{y}^{t}\right)}\times\left[\left(\frac{D_0^{t}\left(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1}\right)}{D_0^{t+1}\left(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1}\right)}\right)\left(\frac{D_0^{t}\left(\boldsymbol{x}^{t},\boldsymbol{y}^{t}\right)}{D_0^{t+1}\left(\boldsymbol{x}^{t},\boldsymbol{y}^{t}\right)}\right)\right]^{1/2} \quad (1)$$

where $D_0^t(\boldsymbol{x}^{t+1}, \boldsymbol{y}^{t+1})$ indicates the distance from the observation in period $t+1$ to the technology given in period t. The first term on the right-hand side measures the change in efficiency between period t and $t+1$. The second term represents the TC, measured as a geometric mean of the frontier shift between t and $t+1$ with respect to two input levels x^t and x^{t+1}. An MI score greater than one indicates a gain in productivity; conversely, a value lower than one indicates deterioration. The same holds for interpreting the EC and TC components of the MI. Value greater than one indicate positive contributions to TFP growth, and values lower than one indicate negative contribution.

2.3.2 The time-varying stochastic frontier inefficiency model

In the analysis, a stochastic frontier "metaproduction function" with time-varying technical inefficiency effects is considered. Approaches using stochastic-frontier production functions have been independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The metaproduction function[9] concept was first introduced by Hayami and Ruttan (1970: 898) to describe the envelope of several production functions for a group of countries, assuming that all countries have access to the same technology. Lau and Yotopoulos (1989: 242) argue that the metaproduction function concept is empirically attractive in cross-country comparisons because it increases the range of variation of the independent variables, and at the same time, increases degrees of freedom by pooling cross-country observation. By doing so, it helps reduce multicollinearity problems that are common when using aggregate time series data.

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[9] "The metaproduction function is defined as the envelope of the production points of all the most efficient countries. It represents a production frontier that each country could reach by importing technology and by investment. Each country may operate at or below the frontier with different efficiencies due to different natural endowments or different economic environments" (Carter and Zhang (1994: 318)).

Technical efficiency is a particularly useful and neutral concept for assessing the performance of former socialist countries because it focuses only on the maximum attainable output level for a given set of inputs. As Brada, King and Ma (1997: 107) argue, technical efficiency is a necessary, thought not sufficient, condition for profit maximization; it is also a necessary condition for fulfilling output plans as they existed in former collective and state-owned farms.

The time-varying technical inefficiency effects model, developed by Battese and Coelli (1992), was used (see Coelli, Rahman and Thirtle (2003) for an empirical application measuring TFP). Other time-varying stochastic frontier models have been proposed by Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990) and Lee and Schmidt (1993).

The stochastic frontier production function with a two-component disturbance term is defined as follows:

$$y_{it} = f\left(x_{it};\boldsymbol{\beta}\right)\cdot \exp\left(v_{it} - u_{it}\right) \qquad (2)$$

where y_{it} is the output for the i^{th} unit at the t^{th} period of observation; $f(x_{it};\ \boldsymbol{\beta})$ is an adequate functional form of a vector, x_{it}, representing the input variables for the i^{th} unit at the t^{th} period of observation and a vector, $\boldsymbol{\beta}$, of parameters to be estimated; v_{it} is the idiosyncratic error assumed to be independently and identically distributed $N(0,\ \sigma_v^2)$; and u_{it} is the time-varying panel-level effect (technical inefficiency effect), which is assumed to be normally distributed $N(\mu,\ \sigma_\mu^2)$. The technical inefficiency effects u_{it} are assumed to be defined as follows:

$$u_{it} = \left\{\exp\left[-\eta\left(t - T_i\right)\right]\right\}\cdot u_i \qquad i = 1, 2,\dots, N; \quad t = 1, 2,\dots, T \qquad (3)$$

where η is the time-varying decay parameter to be estimated. This time-varying specification is such that as t increases the time-varying panel-level effect u_{it} decreases if $\eta > 0$, remains constant if $\eta = 0$, or increases if $\eta < 0$. In addition, if the unit under analysis is observed in the last period T, then it follows that $u_{iT} = u_i$, and u_i is the technical inefficiency effect for the i^{th} unit in the last period of observation. For intermediate periods, the technical inefficiency effects are obtained from the product of u_i, and the resulting value of the exponential function given by $\exp\left[-\eta\left(t - T\right)\right]$. The values of the exponential function depend on the parameter η and the number of intermediate periods $-\eta\left(t - T\right)$. This specification allows the different components of TFP growth (i.e., efficiency change and technical change) to be identified, given that TC is appropriately specified in the production function, but the specification is also limited in that the technical inefficiency effects of different units for a given period t are equal to the same exponential function $\exp\left[-\eta\left(t - T\right)\right]$ of the related technical inefficiency effect for the i^{th} unit in the last period of observation, that is, u_i. In Appendix 2.1 the log-likelihood function of the time-varying technical inefficiency effects model is provided.

2.4 Data description

A panel data set consisting of pooled time series data for the ten CEECs was constructed for the period 1993-2002, based on FAO (2004). Data are compatible across countries because they are based on a common statistical source, following similar standards. Several previous studies have used FAO data for country-level productivity analysis (Fulginiti and Perrin (1997), Suhariyanto and Thirtle (2001), Coelli and Prasada Rao (2003)). We consider one output and four inputs. The output is the net agricultural production valued at 1999-2001 so-called "international dollar"[10] prices. The inputs distinguished are fertilizer, labour, livestock, and machinery. The definition of the variables is as follows. The value of agricultural production has been derived by FAO, by multiplying net production—gross production after deductions of quantities used as seed and feed[11]—by the average of 1999, 2000, and 2001 international commodity prices. These international prices, expressed in so-called international dollars, are derived using a Geary-Khamis (Geary (1958), Khamis (1972)) formula for the agricultural sector[12]. This method assigns a single price to each commodity. Following Hayami and Ruttan (1970) and Fulginiti and Perrin (1997), figures for fertilizer use are obtained by aggregating the use of nitrogen (N), potassium (P_2O_5) and phosphate (K_20) in metric tons of plant nutrient consumed in agriculture. Agricultural labour is measured as the number of people economically active in agriculture, forestry, hunting, or fishing, and also includes people actively searching for employment in agriculture, forestry, hunting, or fishing[13]. Aggregate livestock aggregate cattle, goats, pigs, and sheep[14] into livestock units using the conversion factors defined in Hayami and Ruttan (1985: 450). Machinery is a simple total aggregate of harvester-threshers, milking machines, and tractors in use. Table 2.5 presents summary statistics.

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[10] International prices are expressed in dollar terms and are recovered after assigning a single price to each commodity. For example, one metric ton of wheat has the same price regardless of the country where it was produced. The currency unit in which the prices are expressed has no influence on the indices published.
[11] This is the reason for not including feed and seed in the input series.
[12] The international average prices used in the Geary-Khamis method by FAO are based on prices and quantities of 185 agricultural commodities in 103 countries; see Coelli and Prasada Rao (2003).
[13] Because it also includes people actively searching for employment in agriculture, forestry, hunting or fishing, this variable is a second-best proxy for labor input in agriculture.
[14] Because of their short lifespan in the production cycle, the number of chickens is not included.

Table 2.5 Summary statistics

Country	Mean (standard deviation)				
	Agricultural production (1999-2001, 1000I$)	Machinery (In use)	Labour (Persons)	Fertilizer (Metric tones)	Livestock (LU Head)
Bulgaria	2,985,779	49,718	360,100	175,497	1,281,186
	(188,510)	(2,905)	(77,036)	(34,884)	(248,914)
Czech Rep.	3,933,454	106,322	503,900	331,451	2,291,478
	(171,855)	(8,215)	(40,798)	(36,168)	(316,115)
Estonia	450,566	67,183	91,800	33,604	369,871
	(48,865)	(2,390)	(10,304)	(12,227)	(108,646)
Hungary	5,341,651	112,750	560,999	403,178	1,853,783
	(308,189)	(10,920)	(59,870)	(65,840)	(140,234)
Latvia	718,834	66,940	170,400	54,206	543,462
	(142,768)	(3,472)	(20,452)	(25,419)	(215,449)
Lithuania	1,560,430	106,858	247,400	134,310	1,087,756
	(151,396)	(7,933)	(35,113)	(34,807)	(259,184)
Poland	16,991,842	1,758,016	4,543,503	1,527,167	9,201,816
	(924,923)	(87,488)	(255,357)	(111,238)	(784,304)
Romania	7,985,825	199,340	1,832,397	367,332	5,121,260
	(526,787)	(5,813)	(253,116)	(96,364)	(799,330)
Slovakia	1,720,033	33,339	281,800	109,839	1,082,865
	(155,647)	(4,719)	(17,694)	(11,876)	(211,749)
Slovenia	664,433	102,678	27,400	72,346	506,741
	(27,868)	(12,178)	(8,758)	(8,393)	(15,287)

Note: 1000I$ refers to value expressed in thousand of International (I) Dollar ($). LU refers to Livestock Unit (LU) (see main text).

Source: Author's calculations based on the samples.

2.5 Empirical Model

This subsection specifies the stochastic frontier model with time-varying technical inefficiency effects for panel data. The functional forms most used in empirical research are the Cobb-Douglas and transcendental logarithmic—that is, the second-order flexible functional translog-form—specifications. In this study, a restricted transcendental logarithmic-stochastic frontier metaproduction function was estimated as given by

$$\ln y_{it} = \beta_0 + \sum_{k=1}^{4} \beta_k \ln(x_{kit}) + \sum_{k=2,4} \beta_{kt} \ln(x_{kit})t + \beta_t t + .5\beta_{tt} t^2 + \chi d + v_{it} - u_{it} \quad (4)$$

where y_{it} is agricultural output for the i^{th} unit at the t^{th} period of observation, x_{kit} are the conventional agricultural inputs with k = *1* (machinery input), *2* (labour input), *3* (fertilizer input), and *4* (livestock input), t is a time trend, and t^2 is the squared time trend. Variable d is a dummy variable for the period 1999-2002, accounting for the generalized decrease in agricultural output in the ten CEECs (see above), $\boldsymbol{\beta}$ are parameters to be estimated, $v_{it} \overset{iid}{\sim} N\left(0, \sigma_v^2\right)$ is the error; and $u_{it} \overset{iid}{\sim} N\left(\mu, \sigma_\mu^2\right)$ is the time-varying panel-level effect as defined in Equation (3).

In estimating the model, constant returns to scale (CRS) are imposed. According to Färe, Grosskopf, Norris and Zhang (1994: 74-75) and Grifell-Tatjé and Lovell (1995: 170), this is necessary to obtain the correct benchmark for calculating an MI of TFP, because under variable return to scale, TFP measures may incorrectly reflect the influence of scale. Not imposing CRS introduces a systematic bias in the MI (Grifell-Tatjé and Lovell (1995: 172-173)). The true productivity changes are overstated (understated) for decreasing return to scale and input growth (input contraction), whereas productivity changes are understated (overstated) for increasing return to scale and input growth (input contraction). Because we use aggregate country-level data, it seems plausible to assume CRS (see also Coelli and Prasada Rao (2003)). CRS is guaranteed by imposing the following restrictions in Equation (4):

$$\sum_{k=1}^{5} \beta_k = 1, \qquad \sum_{k=2,4} \beta_{kt} = 0 \tag{5}$$

During estimation, we made several simplifying assumptions. First, in our model specification in Equation (4), we excluded land input for two reasons. Land input in our sample data does not show much variation, and as such, its contribution is difficult to estimate (see Table 2.3). Previous similar country-level analyses of developing and transition countries (see, e.g., Hayami and Ruttan (1970), Kawagoe, Hayami and Ruttan (1985), Carter and Zhang (1994)) have shown that land input does not constitute a particular limiting factor in agriculture[15]. Second, for livestock and labour only, we allowed for the possibility of non-Hicksian—that is, biased—technological change. By so doing, we account for the effect of genetic progress in livestock and the rationalization in labour productivity following privatization after transition, but we do not account for other forms of shifts over time. Finally, when not statistically significant (at the 5 percent significance level) the second order

[15] According to Mathijs and Noev (2004: 82), land appears to be a limiting factor for Bulgaria, a country in which property rights are apparently strong and properly defined. Land may be an important limiting factor in other countries (e.g. The Netherlands) or when estimating (disaggregated) crop production.

interaction terms in the original transcendental logarithmic functional form were dropped during estimation, reducing multicollinearity and saving degrees of freedom.

Once the parameters of the stochastic frontier model have been estimated together with the time-varying technical inefficiency parameter η, the technical efficiencies of production for the i^{th} country at the t^{th} observation are derived through the following expression

$$TE_{it} = E\left[\exp\left(-\eta_{it} \cdot u_i\right)\right] \tag{6}$$

The annual TC can be calculated by evaluating the partial derivative of the stochastic frontier production function with respect to time evaluated at a particular data point. This leads to

$$TC_{it} = \beta_t + \beta_{tt} t + \sum_{k=2,4} \beta_{kt} \ln\left(x_{kit}\right) \tag{7}$$

The derived measures of EC and TC can be used to calculate the MI of TFP growth for each i^{th} country between two consecutive periods, s and t, following Coelli, Prasada Rao and Battese (1998: 233-234). The EC is computed as

$$EC_{i,s/t} = TE_{it} / TE_{is} \tag{8}$$

TC between periods s and t can be calculated from the geometric mean applied to the TC, measured through consecutive periods, as given by

$$TC_{i,s/t} = \left\{\left[1 + TC_{is}\right]\left[1 + TC_{it}\right]\right\}^{1/2} \tag{9}$$

The MI can now be derived by simply multiplying the EC and TC obtained from Equations (8) and (9) as given by

$$TFP_{i,s/t} = EC_{i,s/t} \cdot TC_{i,s/t} \tag{10}$$

2.6 Results and Discussion

This subsection discusses the estimates obtained, and then focuses on TFP growth measures and country-specific technical efficiency scores. Table 2.6 presents the stochastic production frontier estimates. Six out of the ten parameters are statistically significant at the 5 percent significance level. The coefficients of the time trend variable imply positive neutral technological progress, with the stochastic frontier moving upward at an annual rate of about 3.28 percent. The significant negative coefficient on η shows that technical inefficiency effects increased over time. The estimate for γ implies that technical inefficiencies account for

97.44 per cent of the two error terms[16]. Dummy variables capturing the effect of bad weather for the period 1999-2002 are significant and negative, indicating a drop in agricultural output (see above, discussing Table 2.2).

Table 2.6 Stochastic production frontier estimates

Parameter	Estimate	Standard error	z	P>│z│	95 percent confidence interval	
Constant	8.69914	0.18759	46.37	0.000	8.33148	9.06681
ln Machinery	0.15915	0.07185	2.22	0.027	0.01833	0.29997
ln Labour	0.32994	0.08691	3.80	0.000	0.15960	0.50028
ln Fertilizer	0.03687	0.02757	1.34	0.181	-0.01716	0.09091
ln Livestock	0.47404	0.07397	6.41	0.000	0.32907	0.61900
ln Labour*time	-0.00458	0.00415	-1.10	0.270	-0.01272	0.00356
ln Livestock*time	0.00458	0.00415	1.10	0.270	-0.00356	0.01272
Time	0.03192	0.01225	2.60	0.009	0.00790	0.05594
$(\text{Time})^2$	0.00091	0.00189	0.48	0.628	-0.00279	0.00463
Dummy 1999-02	-0.07071	0.02544	-2.78	0.005	-0.12056	-0.02086
Diagnostic statistics						
μ	0.51641	0.17646	2.93	0.003	0.17056	0.86226
η	-0.01581	0.00795	-1.99	0.047	-0.03140	-0.00022
σ^2	0.13378	0.09401				
γ	0.97443	0.01856				
Log-likelihood	114.745					
Number of observations		100				
Number of years		10				
Average production elasticities						
Machinery	0.15915	0.07185				
Labour	0.32995	0.01293				
Fertilizer	0.03687	0.02757				
Livestock	0.49923	0.06354				

Note: The labour-time and livestock-time parameters are equal in absolute value due to imposed CRS restriction; see Equation (5).

Source: Authors' estimations.

Of the inputs, livestock has the highest production elasticity, at about 0.50, followed by labour at 0.33, machinery at 0.16, and fertilizer at 0.04. Although a perfect comparison with other studies is not possible, our estimated production elasticities are very similar to results obtained by Hayami and Ruttan (1970), Kawagoe, Hayami and Ruttan (1985), and Carter and Zhang (1994). Hayami and Ruttan (1970) and Kawagoe, Hayami and Ruttan

[16] The parameter γ is defined as the ratio of σ^2_μ over $\sigma^2_\mu + \sigma^2_v$.

(1985) estimate a metaproduction function for thirty-eight developed countries and forty-three underdeveloped countries respectively. Only Carter and Zhang (1994) take CEECs into account; their study included nine countries, among them Bulgaria, former Czechoslovakia, Hungary, Poland, Romania, and Yugoslavia.

Estimated translog functions often violate regularity conditions, including monotonicity (Corbo and Meller (1979)). In most empirical applications, the required theoretical regularity conditions are simply not checked or tested, and conclusions are often drawn without critically assessing theoretical consistency (Sauer and Hockmann (2005)). Computations of technical efficiency and measurements of productivity when units operate in the "third stage"[17] of a technology are inconsistent, because the third stage represents an economically inefficient region. From our estimates, it appears that monotonicity, as well as concavity, are entirely respected. Table 2.7 list the likelihood-ratio tests of the null hypothesis of CRS for both the Cobb-Douglas and translog specifications. The necessary acceptance of the CRS hypothesis for calculating an MI of TFP was statistically tested and accepted under both specifications.

Table 2.7 Likelihood-ratio test of the null hypothesis of constant return to scale (CRS)

Model	Null hypothesis	Log-likelihood	χ^2 statistic	Critical $\chi^2_{v,\,0.95}$	Decision
Cobb-Douglas	(1) H_0: $\sum\beta_k = 1$ $k = 1,\ldots,4$	114.0775 (115.1300)	2.10482	$\chi^2_{1,\,0.95} = 3.841$	Accept H_0
Restricted Translog	(2) H_0: $\sum\beta_k = 1$ $k = 1,\ldots,4$ $\sum\beta_{kt} = 0$ $k = 2,4$	114.7449 (116.9684)	4.44692	$\chi^2_{2,\,0.95} = 5.991$	Accept H_0

Note: In brackets the Log-likelihood value of the unrestricted model.

Source: Authors' estimations.

The decomposition of TFP growth for each country is presented in Table 2.8 (disaggregated results are available from authors upon request). On average, the estimated TFP growth for the CEECs is 0.29 percent, with a negative EC of 0.05 percent per year and a positive TC of 0.34 percent per year. Given the observed strong decline in output induced by transition in nearly all CEECs (with Bulgaria, Hungary, and Slovenia as exceptions) and

[17] The third neoclassical stage of the production function, defined as the region where the marginal products become negative, is by definition the representation of an inefficient stage, because the use of an extra unit of input leads a decline in output.

accounting for the known immobility of production factors in agriculture, it would have not been surprising to find a decline in TFP. In spite of this, however, we find that agricultural factor productivity rose modestly. This is in line with Brada (1989: 443), who finds that technical progress did not decline when the relation between outputs and inputs was adjusted for systematic changes in efficiency. Analysing TFP growth in the EU-15 from 1973 to 1997, Normile and Leetma (2004: 38) find an average annual rate of TC of about 2 percent[18]. This suggests that the CEECs are currently growing at a lower rate than are the former EU-15 members. Normile and Leetma (2004: 40) also argue that previous new member states have exhibited increases in technology-based productivity growth following EU accession. Evidence was found for the United Kingdom, Denmark, Spain, Portugal, Austria, Finland, and Sweden.

The estimates suggest that productivity growth was driven entirely by TC. The slight decrease in EC indicates that, over time and on average, countries moved farther from the given technology frontier. Although agricultural output and input prices were liberalized, the adjustment of agricultural assets to the reformed system of property rights and to new market mechanism has proceeded rather slowly. Sluggish land privatization, the lack of well-functioning nonland asset markets, and credit constraints hindered farmers in efficiently adapting their input mix to the new output levels after liberalization. In addition, the diffusion of TC (e.g., updated milking parlour systems, modern machinery, farm restructuring), the availability of structural funds from the European Union, and the anticipation of the *acquis communautaire* rules, which also caused changes in the upstream and downstream relationships of primary agricultural production, may have temporarily and negatively affected efficient input use. It is not unusual to find short-run declines in technical efficiency when there is technological absorption Normile and Leetma (2004: 39). Vasavada and Chambers (1986: 958-959) find a similar phenomenon for the United States, showing that adopting new technology initially introduces adjustment costs, especially when farm structure is slow to change.

The best performing country is Slovenia, and the worst-performing country is Latvia. Examining the disaggregated estimates of TFP growth revealed that Latvia was the only

[18] The computed annual rates of technical change from Normile and Leetma (2004: 48) are equal to: 1.85 percent for Austria, 4.14 percent for Belgium, 3.86 percent for Denmark, 3.28 percent for Germany, 4.13 percent for France, 0.67 percent for Finland, -1.80 percent for Greece, -0.62 percent for Ireland, 1.59 percent for Italy, 2.08 percent for the Netherlands, 0.51 percent for Portugal, 1.29 percent for Spain, 3.23 percent for Sweden, and 3.64 percent for United Kingdom.

country with negative growth rates for the period 1994-96. In that period, Latvia's agricultural output contracted and its machinery input increased considerably. Hungary is the only country that does not show significant worsening in EC over time. Obtained results largely agree with those of other studies, particularly for the ranking of annual growth rate of TFP, though differences appear in the estimated absolute values[19]. Similar to Lerman, Kislev, Kriss and Biton (2003: 1009), we find a decrease in the annual growth rate of TFP during 1994-96 for Latvia. Also consistent with Lerman, Kislev, Kriss and Biton (2003), Lithuania has a higher TFP growth rate than do Estonia or Latvia. The finding that Slovenia and Hungary are high-performing countries fits in with Macours and Swinnen (2000: 196), who estimated a crop production function.

Table 2.8 Decomposition of TFP growth in agriculture (1993=1)

	Average annual changes 1993-2002		
Country	Efficiency Change (EC)	Technical Change (TC)	TFP Change
Bulgaria	0.9999	1.0036	1.0035
Czech Rep.	0.9996	1.0031	1.0027
Estonia	0.9991	1.0024	1.0014
Hungary	1.0000	1.0037	1.0036
Latvia	0.9991	1.0019	1.0011
Lithuania	0.9993	1.0029	1.0022
Poland	0.9992	1.0034	1.0027
Romania	0.9994	1.0034	1.0029
Slovakia	0.9996	1.0027	1.0023
Slovenia	0.9995	1.0053	1.0048
Weighted Av.	0.9995	1.0034	1.0029

Note: Weighted average changes have been computed by averaging the estimates of the ten CEECs for the values of agricultural production. Subtracting one from the numbers in the table provides the average annual increase or decrease for the sample period of the TFP growth decomposition.

Source: Authors' estimations.

[19] According to Lerman, et al. (2003), the annual growth rates of TFP for agriculture in the Baltic States from 1992 to 1997 are 2.8 percent for Estonia, -1.2 percent for Latvia, and 3.6 percent for Lithuania. According to Macours and Swinnen (2000: 186-194), the annual growth rates of TFP for agriculture in the other CEECs between 1989 and 1995 are 2.7 percent for the Czech Republic, 1.1 percent for Hungary, -0.4 percent for Poland, 1.2 percent for Slovakia, -1.8 percent for Bulgaria, 0.4 percent for Romania, and -3.4 percent for Slovenia. Data were obtained by averaging the values of the two sub-samples 1989-92 and 1992-95. Estimates for Slovenia were only available for the period 1989-92. The differences in the estimates between our analysis and the other studies are mainly attributable to the different time frame considered in our analysis compared with the other studies.

The estimated country-specific technical efficiency scores[20] (see Table 2.9) differ from what is usually found in market economies. Swinnen and Vranken (2005: 3-4) argue that technical efficiency scores in market economies are typically close to the best-practice frontier. For a given set of inputs, the CEECs obtain a suboptimal output level; in other words, for a given output level, they are using a suboptimal input level. Obtained results indicate that the inevitable collapse in agricultural output consequent to market liberalization was not followed by efficient reallocation of agricultural assets. This suggests that CEECs still have the potential to make large improvements in productivity through more efficient and effective use of inputs.

Table 2.9 Average technical efficiency scores by country for the period 1993-02

	Country				
	Bulgaria	Czech Rep.	Estonia	Hungary	Latvia
TE average	0.8881	0.6769	0.3855	0.9663	0.4129
	(0.221)	(0.220)	(0.226)	(0.216)	(0.217)
	Lithuania	Poland	Romania	Slovakia	Slovenia
TE average	0.5053	0.4513	0.5623	0.6457	0.6319
	(0.220)	(0.216)	(0.232)	(0.222)	(0.223)

Note: Standard errors are reported in brackets and recovered through bootstrapping methods by setting 200 replications for each country and then averaging across observations (Mooney and Duval (1993)).

Source: Authors' estimations.

As Table 2.9 shows, there is great variation in technical efficiency across countries. Hungary performs best and Estonia worst, with technical efficiency scores 0.97 and 0.39 respectively. When comparing our technical efficiency score estimates with the status of agricultural reform (see Table 2.4), it appears that Hungary and Czech Republic were the most advanced in their reforms and among the best-performing countries in technical efficiency. Bulgaria's relatively high performance in technical efficiency can be attributed to

[20] When interpreting the efficiency scores, one should be aware that the estimated technical efficiency scores are always based on the dispersion within a sample, and consequently, only relative to the best practice contained in the sample. In general, results are sensitive to the inclusion or exclusion of additional countries, and to important inputs. Including the relatively more efficient EU-15 member states would probably have resulted in lower estimated technical efficiency scores (i.e., greater distance from best practices) far all the CEECs, though this would not have affected their final ranking. Additionally, the absence of quality adjustments in the input variables may have affected results. It is reasonable to assume that countries with a predominance of large farms (e.g., Czech Republic, Hungary, and Slovakia) are likely to have machinery (e.g., tractors, harvesters, and threshers) with a higher average horsepower than countries where farms are much smaller. Since no quality adjustments were made, the technical efficiency levels of Czech Republic, Hungary, and Slovakia might be somewhat overestimated.

the large contraction in agricultural inputs (particularly labour and land), though the agricultural output level remained rather stable.

Our estimates of technical efficiency largely agree with the general findings of Petrick and Weingarten (2004: 9), who allege that those CEECs countries who did not dismantle the large-scale farming structure from the Soviet period (e.g., Czech Republic, Hungary, and Slovakia), but instead rather adapted their organization to the new regime by shedding labour without destroying the know-how of large scale farming, tended to have a more efficient agricultural sector than these countries that shifted into small-scale farming (e.g., Baltic region). This view contrasts with Sarris, Doucha and Mathijs (1999), who suggest that in terms of technical efficiency, small, individual farms are superior to former cooperatives farms and commercial companies that succeeded state farms.

Rozelle and Swinnen (2004) highlight the importance of initial conditions regarding price distortions and differences in technology and the agri-food chain to the performance of agriculture, at both the country level and in effects of reforms (e.g., price reform effects, property right reforms and farm restructuring, distortions in the exchange relationships). Brada and King (1993: 47-54) and Carter and Zhang (1994: 326) also note that massive privatization of the farm sector does not necessarily imply greater technical efficiency. Large-scale farming allows economization of transaction costs. This holds for both output supply and input demand, particularly in a situation of missing markets and uncertain economic conditions.

2.7 Concluding Remarks

To the knowledge of the authors, this paper constitutes a first attempt to analyze agricultural productivity growth for all ten CEECs that started formal negotiations for EU accession in September 1998. A panel data set consisting of pooled time series data was constructed for the period 1993-2002, and a time-varying stochastic production frontier measuring TFP growth was estimated. TFP growth indexes are constructed using a MI. This enables the TFP measure to be decomposed into EC and TC. The index does not require imposing strong behavioural assumptions, nor using price data, which are both difficult to obtain and unreliable for CEECs.

Our results indicate that despite the decrease in output, TFP growth rates were positive across all ten CEECs. Given the sudden decrease in agricultural output and the well-known immobility of production factors in agriculture, it would not have been surprising to find negative TFP growth. This suggests that the decline in agricultural output is not a suitable indicator of agricultural performance, and that an analysis that only focuses on this aspect provides a partial and misleading interpretation of the success of agricultural reform.

TFP growth was decomposed into EC and TC. The estimated average annual TFP growth was 0.29 percent. On one hand, the estimated TFP changes are limited, so it is expected that for the short run, these countries are likely to remain close to their initial productivity levels. This implies that initial intercountry differences will remain in place for the coming years.

The average EC has been declining by 0.05 percent each year, implying that those countries are moving away from the frontier, increasing the gap between actual and best-practice technology. Investment in human and organizational capital for agriculture could counteract this. In countries characterised by endemic “hidden unemployment”, such as Poland and Slovakia, improvement in general macroeconomic conditions could also improve labour efficiency by facilitating outflow of labour from agriculture.

TC, measured by the annual shift in the frontier of the best-practice country, showed an average annual improvement of 0.34 percent. On one hand, TC embodied in new available equipment is likely to have been slowed down by ill-defined property rights, high transaction costs, and poorly operating capital markets. On the other hand, the disembodied TC related to improvements in techniques or organization might have been penalized by the organizational restructuring of agriculture (privatization and farm adjustment).

Given the relatively higher rate of TC within the former EU-15 compared to the CEECs, and the expected increase associated with EU accession, the contribution of TC to TFP is likely to increase in the long run. New available technologies, better farm management practices, and improved quality of agricultural inputs are important elements boosting TC in the CEECs. Improving the functioning of the land market and the modernization of capital stock is necessary to foster productivity growth in transition economies.

We found that countries characterized by large-scale operators, such as Bulgaria, Czech Republic, Hungary, and Slovakia, were relatively technically efficient. Technical efficiency scores were low in countries where small individual family farms predominated. This confirms the view that large-scale farming performs better than does small-scale farming for situations with missing markets and uncertain economic conditions.

Appendix 2.1

The log-likelihood function of time-varying technical inefficiency effects model

The log-likelihood function of the time-varying technical inefficiency effects model presented in section 2.3.2 is given by:

$$\ln L = -\frac{1}{2}\left(\sum_{i=1}^{N} T_i\right)\left\{\ln(2\pi) + \left(\sigma_S^2\right)\right\} - \frac{1}{2}\sum_{i=1}^{N}(T_i - 1)\ln(1-\gamma)$$

$$-\frac{1}{2}\sum_{i=1}^{N}\ln\left\{1 + \left(\sum_{t=1}^{T_i}\eta_{it}^2 - 1\right)\gamma\right\} - N\ln\{1 - \Phi(-\tilde{z})\} - \frac{1}{2}N\tilde{z}^2$$

$$+\sum_{i=1}^{N}\ln\{1 - \Phi(-z_i^*)\} + \frac{1}{2}\sum_{i=1}^{N} z_i^{*2} - \frac{1}{2}\sum_{i=1}^{N}\sum_{t=1}^{T_i}\frac{e_{it}^2}{(1-\gamma)\sigma_S^2} \qquad (I.1)$$

The log-likelihood function defined in equation (I.1) is presented in a reparameterized form where $\sigma_S = \left(\sigma_u^2 + \sigma_v^2\right)^{1/2}$, $\gamma = \sigma_u^2/\sigma_S^2$, $e_{it} = y_{it} - f(x_{it};\boldsymbol{\beta})$, $\eta_{it} = \exp\{-\eta(t - T_i)\}$, $\tilde{z} = \mu/\left(\gamma\sigma_S^2\right)^{1/2}$, and $\Phi(\ )$ represents the cumulative distribution function of the standard normal distribution, and

$$z_i^* = \frac{\mu(1-\gamma) - \gamma\sum_{t=1}^{T_i}\eta_{it}e_{it}}{\left[\gamma(1-\gamma)\sigma_S^2\left\{1 + \left(\sum_{t=1}^{T_i}\eta_{it}^2 - 1\right)\gamma\right\}\right]^{1/2}} \qquad (I.2)$$

By maximizing the log-likelihood function (I.1) the estimates for the relevant coefficients, η, μ, σ_v, and σ_u are obtained. The mean estimate of u_i is given by the expected value of the conditional distribution $f(u|e)$:

$$E(u_{it}|e_{it}) = \tilde{\mu}_i + \tilde{\sigma}_i\left\{\frac{\phi(-\tilde{\mu}_i/\tilde{\sigma}_i)}{1 - \Phi(-\tilde{\mu}_i/\tilde{\sigma}_i)}\right\} \qquad (I.3)$$

where

$$\tilde{\mu}_i = \frac{\mu\sigma_v^2 - \sum_{t=1}^{T_i}\eta_{it}e_{it}\sigma_u^2}{\sigma_v^2 - \sum_{t=1}^{T_i}\eta_{it}^2\sigma_u^2} \qquad (I.4)$$

$$\tilde{\sigma}_i^2 = \frac{\sigma_v^2\sigma_u^2}{\sigma_v^2 + \sum_{t=1}^{T_i}\eta_{it}^2\sigma_u^2} \qquad (I.5)$$

The predictor of $E\{\exp(-u_{it})|e_{it}\}$ can be obtained by using the following expression:

$$E\{\exp(-u_{it})|e_{it}\} = \left[\frac{1 - \Phi\{\eta_{it}\tilde{\sigma}_i - (\tilde{\mu}_i/\tilde{\sigma}_i)\}}{1 - \Phi(\tilde{\mu}_i/\tilde{\sigma}_i)}\right]\exp\left(-\eta_{it}\tilde{\mu}_i + \frac{1}{2}\eta_{it}^2\tilde{\sigma}_i^2\right) \qquad (I.6)$$

CHAPTER 3

Transition-induced adjustments to the mix of agricultural outputs: A case study of Hungary and Poland

Abstract

In the 1990s many Central and Eastern European Countries (CEECs) initiated the so-called transition reform from the former centrally planned regime to a free market economy. Farmers were suddenly exposed to a change in the economic environment: a move from a highly distorted and subsidised system to a more market oriented system. As a result of the worsened terms of trade following the economic reform, the supply of many agricultural products, particularly livestock products, diminished. An output distance function is estimated for Hungary and Poland. The aim is to analyze to what extent the mix of agricultural output changed after transition and to explain the degree of allocative inefficiencies. A generalised maximum entropy estimator was used exploiting non-sample information (NSI). Results indicate that it is going to be difficult to increase chicken meat getting rid of the other agricultural products. Adjustment costs were greater and increasing over time for Hungary as compared to Poland. The model detected overspecialization for sugar beet production. In the second half of the 1990s the degree of complementarity and substitutability is increased.

Tonini, A., R. Jongeneel. Transition-induced adjustments to the mix of agricultural outputs: A case study of Hungary and Poland. Submitted for publication in the *Journal of Agricultural and Applied Economics*.

3.1 Introduction

In the 1990s many Central and Eastern European Countries (CEECs) initiated the so-called transition reform from the former centrally planned regime to a free market economy. The reform implied liberalizing prices and removal of production and consumption subsidies. Farmers were suddenly exposed to a change in the economic environment: a move from a highly distorted and subsidised system to a more market oriented system. In the first half of the 1990s, the output-to-input price ratio in agriculture decreased by 30 percent in Hungary and about 70 percent in Poland (Rozelle and Swinnen (2004: 420)). As a result of the worsened terms of trade following the economic reform, the supply of many agricultural products, particularly livestock products, diminished as discussed in Macours and Swinnen (2000: 172-176). This was followed by a decline in the demand for conventional agricultural inputs.

A series of institutional changes led to privatization and restructuring of farms (Tonini and Jongeneel (2006: 38-42)). The privatization process required a proper definition and attribution of legal and property rights for agricultural assets. Former collective land was mainly restituted to former owners. Nonland assets were only partly restituted and mostly privatized. Farm restructuring proceeded slowly because of a lack of well-functioning credit markets. The bimodal or dual farm structure, typical in many CEECs during the pretransition period, persisted in many CEECs also afterwards. Hungary features a dual farm spectrum, with a symbiosis between small and large-scale farms (Juhasz (1991: 405-409)). Poland, however, presents a fragmented spectrum of small farms with large inefficiencies due to a poorly functioning land market (Csaki and Lerman (2002: 313-315)).

The aim of the paper is to provide insights on how the output mix composition in agriculture changed after transition. The objective is on modelling how the transition-induced adjustments to the mix of agricultural outputs differ between Hungary and Poland and on determining the potential implications. These two countries shed light on the adjustments from different starting positions. The paper recovers output substitution and allocative efficiency measures. Output substitution measures provide information on the curvature of the production possibility curve (PPC) which is strictly related to the marginal rate of transformation (MRT). Allocative efficiency measures the ability to use the outputs in optimal proportions, given their respective prices and production technology[21]. In doing so a multi-output agricultural production technology is modelled through an output-oriented distance function.

Not only data collection changed in the CEECs: the system the data are supposed to describe has also undergone tremendous structural changes (Hallam (1998: 125)). Frequently data series are either not available or, if available, are too short for conventional econometric estimations. For example, the number of parameters to be estimated may be larger than the number of available data points (i.e. "ill-posed" problem). Furthermore, the parameter estimates are frequently unstable due to collinear variables (i.e. "ill-conditioned" problem) (Paris and Howitt (1998)). In order to address the objective of this paper, therefore a relevant estimation technique will be selected.

By using a generalised maximum entropy (GME) estimator as discussed in Golan, Judge and Miller (1996), Fomby and Carter Hill (1997), and Mittelhammer, Judge and Miller (2000), the paper provides a useful empirical basis for dealing with an "ill-posed" and "ill-conditioned" problem. In doing so, sample information (SI) and non-sample information (NSI) are reconciled through a mixed estimation approach. SI comprises information contained in sample data. NSI includes all information that it is available to the researcher prior to the sampling process. It may come from theory, previous studies or researcher's knowledge. Using a mixed estimation procedure, final parameter estimates are not only near to the original sample data but also largely in accordance with economic theory.

The paper is set out as follows. Section 3.2 describes the model and the related measures. Section 3.3 deals with the empirical model and estimation. Section 3.4 describes the SI, whereas section 3.5 treats the NSI. Section 3.6 provides the model estimation results. Finally the paper ends with concluding remarks in section 3.7.

3.2 The economic model and measures

This section presents the economic model and derived production measures. In order to recover output substitution and allocative efficiency measures for a multi-output setting, a model able to characterise multi-output technologies is required. A distance function framework appears particularly suitable for analysing multi-output production technology in

[21] For a more detailed treatment on the output substitution and allocative efficiency concepts see Coelli, Prasada Rao, O'Donnell and Battese (2005).

CEECs. Traditional production function approaches are not able to model multi-output technologies unless the outputs are aggregated into a single output index. Alternative approaches to distance function approaches are cost and profit functions that require strict behavioural assumptions, which are not always satisfied for CEECs (Coelli (2002)).

Introduced by Shepard (1970) the distance function expresses the maximum technically attainable output for a given set of inputs (following an output orientation). Distance function have been applied in particular for efficiency and productivity analysis (for example see Coelli and Perelman (1996), Bjorndal, Koundouri and Pascoe (2002), Brümmer, Glauben and Thijssen (2002), and Morrison-Paul, Johnston and Frengley (2002a-2002b) among others).

Following Morrison-Paul, Johnston and Frengley (2002: 326-327) an output distance function is defined as $D_o(\mathbf{x},\mathbf{y}) = min\{\theta : (\mathbf{y}/\theta) \in P(\mathbf{x})\}$, where θ is a scalar representing the set of input/output combinations which provide the maximum output expansion, **x** and **y** the input and output vectors respectively, and $P(\mathbf{x})$ the output set. In the output orientation $D_o(\mathbf{x},\mathbf{y}) \leq 1$ if $\mathbf{y} \in P(\mathbf{x})$ and $D_o(\mathbf{x},\mathbf{y}) = 1$ if **y** is on the outer boundary of $P(\mathbf{x})$, underlining that the production unit is operating on the production surface.

Distance function-based output elasticities can be recovered following Morrison-Paul, Johnston and Frengley (2002: 330) as follows

$$\varepsilon_{DO,g} = \partial \ln D_0 / \partial \ln y_g = \partial D_0 / \partial y_g \cdot (y_g / D_0) = \partial y_l / \partial y_g \cdot (y_g / y_l) = \varepsilon_{y_{l,g}} \qquad (1)$$

where $\varepsilon_{y_{l,g}}$ reflects the tradeoffs of y_l and y_g as embodied in the PPC keeping fixed all inputs levels. Within a distance function context, $\varepsilon_{y_{l,g}}$ represents the implicit share or contribution of y_g to y_l which represents the change in overall output for given inputs in an output distance function framework. Distance-function input elasticities can be derived similarly and their interpretation indicates the impact on production for a change in a given input.

Using duality theory, Färe (1988: 93-94) and Färe and Primont (1995: 50) define the revenue-deflated output shadow price as the partial derivative of the output distance function for an output *g*, as given by $r_g^*(\boldsymbol{x},\boldsymbol{y}) = D_{O,g}(\boldsymbol{x},\boldsymbol{y})$, where single subscript indicates first partial derivative with respect to output y_g. The r_g^* measure can be interpreted as the marginal product notion. More precisely, they give information on the relative valuation of the outputs in terms of its contribution to overall output. The ratios of these revenue-deflated relative output shadow prices represent the slope of the PPC and therefore the MRT between two outputs as given by $MRT_{g,h} = \left(r_g^* / r_h^*\right)$. In the case of revenue maximisation the $MRT_{g,h}$ can be compared with the output price ratio p_g / p_h.

As suggested by Grosskopf, Margaritis and Valdmanis (1995: 578), since the $MRT_{g,h}$ between two outputs will vary with the choice of the output ratio a more interpretable measure of the $MRT_{g,h}$ can be derived by normalising the $MRT_{g,h}$ by the relative output ratio as given by

$$sub_{g,h} = D_{O,g}(\boldsymbol{x},\boldsymbol{y}) / D_{O,h}(\boldsymbol{x},\boldsymbol{y}) \cdot y_g / y_h = \left(r_g^* / r_h^*\right) \cdot y_g / y_h \tag{2}$$

where $sub_{g,h}$ represents the ratio of $MRT_{g,h}$ relative to the output mix, hence a normalised MRT (i.e. unit less). For an MRT's interpretation, see Appendix 3.1. When $sub_{g,h}$, is bigger than one it is difficult to move away from output *g*, indicating that the outputs *g* and *h* are difficult to substitute. The opposite holds when $sub_{g,h}$, is less than one (Morrison-Paul, Johnston and Frengley (2002b: 139)). Additionally, the $sub_{g,h}$ ratio can be directly compared with the revenue ratio $RV_g / RV_h = p_g y_g / p_h y_h$ in order to evaluate discrepancies from revenue maximisation (i.e. allocative inefficiency).

Additional information about the PPC curvature or output substitutability can be recovered via the distance function Morishima elasticity as discussed in Blackorby and Russell (1989), Grosskopf, Margaritis and Valdmanis (1995), Morrison-Paul, Johnston and Frengley (2002a-2002b), and Mundra and Russell (2004). Blackorby and Russell (1989: 882-883) show that if there are more than two outputs the Morishima substitution elasticity is preferable to the Allen substitution elasticity, since it preserves the Hicksian concept of substitutability[22]. The Morishima elasticity for an output-based distance function following Morrison-Paul, Johnston and Frengley (2002b: 140) is

$$M_{g,h} = -d \ln\left(D_{o,g} / D_{o,h}\right) / d \ln\left(y_g / y_h\right) = y_g \cdot \left[\left(D_{o,gh} / D_{o,h}\right) - \left(D_{o,gg} / D_{o,g}\right)\right]$$
$$= \left(y_g / D_{o,h}\right) \cdot \partial D_{o,h} / \partial y_g - \left(y_g / D_{o,g}\right) \cdot \partial D_{o,g} / \partial y_g \tag{3}$$

where the single and double subscripts indicate first and second order partial derivatives of the output distance function. The components of $M_{g,h}$ are elasticities of the revenue-deflated relative output shadow prices r_h^* and r_g^* for output y_g. The expression after the first equals

[22] The Hicksian concept of substitutability is based on three main requirements according to Blackorby and Russell (1989). The first condition requires a measure of curvature, or ease of substitution. The second condition requires information about relative factor shares so that it is possible to measure the effects of changes in prices or quantity ratios on relative factor shares. The third condition requires a measure which is a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio.

sign can be interpreted as the ratio of the percentage change in shadow prices induced by a one percent increase in the output ratio. Look at the decomposition after the third equals sign: the first component indicates how the valuation of y_h is modified when y_g changes, where $\partial \ln D_{o,h} / \partial \ln y_g = \partial \ln r_h^* / \partial \ln y_g = \varepsilon_{h,g}$; the second part provides information about the curvature of the distance function representing the impact of a change in $(\ln y_g)^2$, where $\partial \ln D_{o,g} / \partial \ln y_g = \partial \ln r_g^* / \partial \ln y_g = \varepsilon_{g,g}$.

Following Mundra and Russell (2004: 7) if $M_{g,h} > 0$, output h is a Morishima substitute for output g, which means that by increasing the quantity of the h^{th} output, the shadow price of output g increases relative to the shadow price of output h; if $M_{g,h} < 0$, output h is a Morishima complement for output g. These elasticities cannot be symmetrical because when there are more than two outputs there are infinite directions in which the curvature of the PPC can be measured[23].

3.3 The empirical model and estimation

This section explains the empirical model and describes the estimation procedure. For empirical implementation of the distance function a functional form must be chosen. One of the most frequently encountered functional form in this area is the Cobb-Douglas (Battese and Coelli (1992, 1995)). However in a multi-output and –input setting as stated by Morrison-Paul, Johnston and Frengley (2002a: 327), “it is important to minimize a priori restrictions on the relationships among outputs and inputs, if sufficient degrees of freedom are available”. Therefore, when the focus is on measuring substitution effects, flexible functional forms are desirable.

A transcendental logarithmic (translog) output distance function is specified in order to allow output substitution measures to be recovered. This results in the following specification with $g = 1,\ldots,$G outputs and $k = 1,\ldots,$K inputs:

---

[23] An intuitive explanation of the asymmetry of $M_{g,h}$ depends on which output is held fixed in the ratio y_g / y_h. For example, a change in y_g in the output ratio y_g / y_h will affect r_g^* in a particular way. The same percentage change in the output ratio y_g / y_h can be obtained by changing y_h. However, this will probably affect r_h^* in a different way than the change in y_g that follows a change in r_g^*.

$$\ln D_{oi} = \alpha_0 + \sum_g \alpha_g \ln y_{gi} + 0.5 \sum_g \sum_h \alpha_{gh} \ln y_{gi} \ln y_{hi} + \sum_k \beta_k \ln x_{ki} + 0.5 \sum_k \sum_l \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_k \sum_g \beta_{kg} \ln x_{ki} \ln y_{gi} + e_i \quad (4)$$

where i represents the i^{th} observation in the sample, g and h indicates outputs, k and l indicates inputs, and e_i is a random error. Six outputs (milk/beef/veal (y_1), chicken meat (y_{chi}), pork (y_{por}), cereals (y_{cer}), potatoes (y_{pot}), and sugar beet (y_{sug})) and five inputs (fertilisers (x_{fer}), labour (x_{lab}), land (x_{lan}), livestock (x_{liv}) and machinery (x_{mac})) are distinguished.

In order to satisfy the required linear homogeneity in outputs, the following set of restrictions in the output distance function equation (4) must apply

$$\sum_g \alpha_g = 1, \qquad \sum_h \alpha_{gh} = 0 \quad (5)$$

An alternative way to impose the linear homogeneity restriction in equation (4) follows by noting that $D_o(\mathbf{x}, \zeta\mathbf{y}) = \zeta D_o(\mathbf{x}, \mathbf{y})$. Therefore by simply selecting a g_h output (y_1) and substituting for $\zeta = 1/y_1$ we get $D_o(\mathbf{x}, \mathbf{y}/y_1) = D_o(\mathbf{x}, \mathbf{y})/y_1$. The specification including output homogeneity is:

$$\ln(D_{oi}/y_{1i}) = \alpha_0 + \sum_g \alpha_g \ln y^*_{gi} + 0.5 \sum_g \sum_h \alpha_{gh} \ln y^*_{gi} \ln y^*_{hi} + \sum_k \beta_k \ln x_{ki} + 0.5 \sum_k \sum_l \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_k \sum_g \beta_{kg} \ln x_{ki} \ln y^*_{gi} + e_i \quad (6)$$

where $y^*_{gi} = y_{gi}/y_{1i}$ from which it follows that with homogeneity in output imposed the summation sign over g now implies summation over only five outputs[24]. Using logarithmic properties, equation (6) can be rewritten as:

$$\ln(D_{oi}) - \ln(y_{1i}) = \alpha_0 + \sum_g \alpha_g \ln y^*_{gi} + 0.5 \sum_g \sum_h \alpha_{gh} \ln y^*_{gi} \ln y^*_{hi} + \sum_k \beta_k \ln x_{ki} + 0.5 \sum_k \sum_l \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_k \sum_g \beta_{kg} \ln x_{ki} \ln y^*_{gi} + e_i \quad (7)$$

or

[24] Since the resulting estimates have to provide a consistent interpretation with the expected sign of production theory, the negative sign on the dependent variable (y_1) can be ignored during estimation, so that the model can be assessed more conveniently by making the estimates better comparable with the estimates produced by traditional production function models. This reverses the sign of the estimated coefficients without affecting the overall interpretation (for an example see Coelli and Perelman (2000)).

$$-\ln(y_{1i}) = \alpha_0 + \sum_g \alpha_g \ln y^*_{gi} + 0.5\sum_g \sum_h \alpha_{gh} \ln y^*_{gi} \ln y^*_{hi} + \sum_k \beta_k \ln x_{ki} + 0.5\sum_k \sum_l \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_k \sum_g \beta_{kg} \ln x_{ki} \ln y^*_{gi} - \ln(D_{oi}) + e_i \tag{8}$$

Symmetry in cross effects between outputs is imposed by setting $\alpha_{gh} = \alpha_{hg}$, $\forall$ *g, h = 1,…, 5*. The remaining of this section discusses the estimation procedure used in the paper. First the main advantages of the estimation method are described and then the formal econometric model is elaborated.

A GME estimator is adopted to estimate the multi-output distance function technology. Maximum entropy techniques over the more traditional econometric approaches have several advantages which are discussed in Golan, Judge and Miller (1996), Fomby and Carter Hill (1997), and Mittelhammer, Judge and Miller (2000: cd-rom, E.3). Here we briefly list the most relevant characteristics for the problem at hand. First, the entropy criterion is able to provide estimates when the number of parameters to be estimated exceeds the number of data points (i.e. negative degrees of freedom). Second, it is a relatively more efficient estimation method for a small sample, since it considers each observation of sample data rather than the moment conditions. Third, it is relatively less influenced by outliers because of the weighting between signal and noise in the objective function (i.e. Stein-like estimators). Finally, it is a robust estimator even when disturbances are not normally distributed and/or the exogenous variables exhibit high condition numbers. These properties make maximum entropy approaches particularly suited for applications related to CEECs where data sets are limited to few yearly/periodic data points and the underlying generating process is frequently unknown.

The entropy criterion comprises a dual-loss function in which usually equal weight is attributed to signal (i.e. the deterministic part of the model) and noise (i.e. the entropy from the stochastic part). In the entropy formulation, as discussed in Golan, Judge and Miller (1996: 85-101), Fomby and Carter Hill (1997: 3-24), and Mittelhammer, Judge and Miller (2000: cd-rom, E.3), the parameters are reparameterised in terms of proper probabilities. In order to reparameterise the parameter support space, the parameters α_{gh}, for example, need to be reparameterised in terms of a proper parameter support space and related proper probabilities. The parameter support space is defined as follows $\sum_m z_{ghm}\tau_{ghm} = \alpha_{gh}$, $\forall g, h$

where $\mathbf{z_{gh}} = \lfloor z_{gh1}, z_{gh2}, \cdots, z_{ghM} \rfloor'$ is a $M \times 1$ vector of parameter supports such that $z_{gh1} < z_{gh2} < \cdots < z_{ghM}$ and M is a fixed integer with dimension $M > 2$. The parameter support space spans a uniform discrete space centred on zero, which contains the expected parameter realisation in the interval $[-a, a]$, where $-a$ and a are the bounds of the interval. The corresponding proper probabilities associated with the parameter support space are defined as follows where $\mathbf{p_{gh}} = \lfloor p_{gh1}, p_{gh2}, \cdots, p_{ghM} \rfloor'$ is a $M \times 1$ vector of unknown probabilities such that $\mathbf{p_{gh}} \in [0,1]$, $\sum_m p_{ghm} = 1$. The parameter estimates for α_{gh} can be recovered as follows:

$$\mathbf{z}_{gh}'\mathbf{p}_{gh} = \sum_m z_{ghm} p_{ghm} = \alpha_{gh}, \qquad \text{for } g, h = 1, \ldots, 5. \tag{9}$$

The disturbance term is also treated as an unknown parameter to be estimated and it is defined as follows $\sum_n v_{in} w_{in} = e_i$, $\forall i$ where $\mathbf{v}_i = [v_{i1}, v_{i2}, \cdots, v_{iN}]'$ is a $N \times 1$ row vector of disturbance term supports such that $v_{i1} < v_{i2} < \cdots < v_{iN}$ and N is a fixed integer, $\mathbf{w}_i = [w_{i1}, w_{i2}, \cdots, w_{iN}]'$ is a $N \times 1$ vector of unknown probabilities such that $\mathbf{w}_i \in [0,1]$, $\sum_n w_{in} = 1$. The estimates for the disturbance term e_i can be recovered as follows:

$$\mathbf{v}_i'\mathbf{w}_i = \sum_n v_{in} w_{in} = e_i, \qquad \text{for } i = 1, \ldots, \mathrm{I}. \tag{10}$$

In order to estimate both parameters and error terms, the number of support points and the support bounds need to be chosen. The number of support points is set to five for both the parameter (M = 5) and the error (N = 5) supports, for further details see Golan, Judge and Miller (1996: 138-140). For the output support space z_ζ whit $\zeta = g0, gm, ghm, km$ an uninformative support space in which the support interval is centred on zero and bounded between $[-a, a]$ is set up with $|a| = 10^3$. The error support bounds are specified following the widely accepted three-sigma rule discussed in Pukelsheim (1994) and Golan, Judge and Miller (1996: 88). The error support bounds span a uniform distribution centred on zero and with an error support space defined as $(-3\tilde{\tau}, -1.5\tilde{\tau}, 0, 1.5\tilde{\tau}, 3\tilde{\tau})$, where $\tilde{\tau}$ is the empirical standard deviation of the dependent variable in the model.

In the estimation several simplifying assumptions are made. First as it is usually done in the estimation of traditional single output production function, it is assumed that the observed outputs are on the production possibility surface. This results in D_{0i} = 1 and consequently $\ln(D_{0i}) = 0$. A similar approach was also applied by Grosskopf, Hayes and Hirschberg (1995: 287-288). This assumption is necessary because in our study we are considering not a cross-section of countries but rather two individual countries, which makes it impossible to model a frontier different from the PPC of Hungary and Poland. Second since the focus is on output substitution, the second order terms for the inputs β_{kl} are set to zero. At the same time given the low correlation between outputs and inputs, the second order interactions β_{kg} are also set to zero. In so doing priority is given in increasing the available degrees of freedom to the detriment of some flexibility.

Reparameterising the model according to a GME approach transforms equation (8) into the following equation

$$
\begin{aligned}
-\ln(y_{1i}) = {} & \sum_{m=1}^{5} z_{0m} p_{0m} 1 + \sum_g \sum_{m=1}^{5} z_{gm} p_{gm} \ln y^*_{gi} + 0.5 \sum_g \sum_h \sum_{m=1}^{5} z_{ghm} p_{ghm} \ln y^*_{gi} \ln y^*_{hi} + \\
& \sum_k \sum_{m=1}^{5} z_{km} p_{km} \ln x_{ki} + 0.5 \sum_k \sum_l \sum_{m=1}^{5} z_{klm} p_{klm} \ln x_{ki} \ln x_{li} + \\
& \sum_k \sum_g \sum_{m=1}^{5} z_{kgm} p_{kgm} \ln x_{ki} \ln y^*_{gi} + \sum_{j=1}^{J} v_{in} w_{in}
\end{aligned}
\qquad (11)
$$

The GME criterion maximises the cumulative joint entropy representing the parameters ($\alpha_0, \alpha_g, \alpha_{gh}, \beta_k$) and the stochastic error term e_i defined under (10). By rewriting the proper probabilities associated with each parameter using compact vector notation we obtain $\mathbf{p} = (p_{0m}, p_{gm}, p_{ghm}, p_{km})$ so that we can write the GME objective criterion as given by:

$$\max_{p,w} H(\mathbf{p}, \mathbf{w}) = -\mathbf{p}' \ln \mathbf{p} - \mathbf{w}' \ln \mathbf{w} \qquad (12)$$

subject to the moment or consistency constraint given by equation (10) in which β_{kl} and β_{kg} are set to zero and the GME adding-up conditions for the proper probabilities as given by:

$$\sum_{m=1}^{5} p_{0m} = \sum_{m=1}^{5} p_{gm} = \sum_{m=1}^{5} p_{ghm} = \sum_{m=1}^{5} p_{km} = \sum_{n=1}^{5} w_{in} = 1 \qquad (13)$$

and the required output homogeneity and symmetry conditions. The primal solution to the GME problem obtained by solving the first order Lagrangian conditions yields the optimal values for the proper probabilities related to signal and noise parts. From the estimated proper probabilities and the specified parameter supports it is then possible to recover the estimates for the model parameters as given by $\tilde{\alpha}_0 = \sum_{m=1}^{5} z_{0m} \tilde{p}_{0m}$, $\tilde{\alpha}_g = \sum_{m=1}^{5} z_{gm} \tilde{p}_{gm}$, $\tilde{\alpha}_{gh} = \sum_{m=1}^{5} z_{ghm} \tilde{p}_{ghm}$, $\tilde{\beta}_k = \sum_{m=1}^{5} z_{km} \tilde{p}_{km}$, and $\tilde{e}_i = \sum_{n=1}^{5} v_{in} \tilde{w}_{in}$.

3.4 Sample information

The model was estimated using data from the publicly available FAO statistical database (FAO (2005)). Time series data for the period 1991-2001 were used for Hungary and Poland. In this way, only post-transition data were used during estimation. The FAO statistical database yielded agricultural output and input variables. The output variables were selected according to their importance in the value of agricultural production of Hungary and Poland (EC (2002a, 2002b)). The variables were aggregated using a discrete approximation to the Divisia Index (Tornqvist or translog) available in SHAZAM version 10 (Whistler, White, Wong and Bates (2004: 373-376)). Variables were indexed to the base year 1991. Milk production was aggregated with beef and veal production because in Hungary and Poland beef and veal production is a by-product of milk production (EC (2002a, 2002b)). Cereals were obtained for Hungary by aggregating barley, maize, oats, rye, and wheat, plus rapeseed and sunflower; cereals for Poland were the aggregation of barley, mixed grain, rye, and wheat, plus rapeseed.

As regards the input variables, livestock was obtained from the aggregation in livestock units of cattle, chickens and pigs using conversion factors (Hayami and Ruttan (1985: 450)). Fertilisers were defined as the total quantity of nitrogenous, potash, and phosphate fertilisers consumed in agriculture. Labour was measured as the economically active population in agriculture, i.e. people engaged in or seeking work in agriculture, hunting, fishing, or forestry. Land is arable land plus permanent pasture. Machinery is measured as number of tractors in use. Summary statistics are provided in Appendix 3.2.

3.5 Non-sample information

NSI during estimation can be added either deterministically or stochastically through restrictions that act as constraints in the estimation procedure (Judge, Griffiths, Hill, Lütkepohl and Lee (1985: 54-77)). It can be introduced deterministically when it should exactly hold and only refers to relationships in parameters. It can be included in a stochastic way when the researcher has some prior uncertainty or the restriction depends both on parameters and on observations. In this case, the stochastic component of the restriction should take into account the sample scale of the data as well as the uncertainty attached to the NSI prior estimates.

Initially a set of restrictions on outputs measures is elaborated and then several restrictions on inputs are also considered. The first restriction (henceforth called NSI1) is specified for each output as follows:

$$\varepsilon_{D_{o,m}} = \varepsilon_{y_{1,g}} = \alpha_g + \sum_h \alpha_{gh} \ln y_{hi} = \hat{\varepsilon}_{y_{1,g}} + e_{NSI1,i} \quad (14)$$

where $\hat{\varepsilon}_{y_{1,g}}$ represents the prior estimates. Since the relative percentage change in overall output could not be greater than the change in a single output, *ceteris paribus*, the prior estimates are defined in order to define inelastic responses on output elasticities. This is consistent with the results found in many empirical papers (for some examples see Morrison-Paul, Johnston and Frengley (2002a, 2002b)). In addition, equal non sample estimates are specified for the output elasticities where $\hat{\varepsilon}_{y_{1,g}}$ is defined as follows $\hat{\varepsilon}_{y_{1,g}} = -\frac{1}{G}$ with G being the number of outputs. The error term $e_{NSI1,i}$ is reparameterised such that:

$$e_{NSI1,i} = \sum_{n=1}^{5} v_{NSI1/n,i} w_{NSI1/n,i} \,, \quad \forall i \quad (15)$$

where v_{NSI1} is the support for the error term and w_{NSI1} represents the unknown probabilities to be estimated for the error term attached to NSI1. The support for the error term is consistently specified such that a uniform deviation of $\left|\frac{1}{G}\right|$ around the expected value is allowed. This spans a uniform error support space for the NSI1 such that the elasticities based on output distance function are contained in the following interval $-\frac{2}{G} < \varepsilon_{y_{1,g}} < 0$. The number of support points for the NSI1 error is defined at $N = 5$.

As a second restriction (henceforth called NSI2), the relationships between the revenue-deflated output shadow prices and the revenue ratios is exploited. To do so, external information to sample data on revenue ratios had to be used. The NSI2 restriction is specified as follows

$$\left(sub_{g,h}\right)_i = \left(r_g^* / r_h^*\right)_i \cdot \left(y_g / y_h\right)_i = \left(\varepsilon_{D_{O,g}} / \varepsilon_{D_{O,h}}\right)_i = p_{gi} y_{gi} / p_{hi} y_{hi} + e_{NSI2,i} \quad (16)$$

The error term is reparameterised as given by

$$e_{NSI2,i} = \sum_{n=1}^{5} v_{NSI2/n,i} w_{NSI2/n,i} , \qquad \forall i \tag{17}$$

where v_{NSI2} is the support for the error term and w_{NSI2} the unknown probabilities for the error term. The support for the error term is defined relying on the empirical standard deviation of the revenue ratio $p_{gi} y_{gi} / p_{hi} y_{hi}$. This spans a uniform distribution around the empirical revenue ratios such that $-3 \cdot \tilde{\sigma}_{p_{gi} y_{gi} / p_{hi} y_{hi}} \leq \left(sub_{g,h}\right)_i \leq 3 \cdot \tilde{\sigma}_{p_{gi} y_{gi} / p_{hi} y_{hi}}$. The number of support points for the error $e_{NSI2,i}$ is defined at $N = 5$. It was necessary to specify an error term in (16) because the restriction was observation-dependent. The effect of inserting NSI2 was to impose mild revenue maximisation, since deviations were allowed in equation (16) due to the stochastic term further specified in (17)[25].

For the input variables we required the distance function to follow the regularity conditions from economic production theory, viz. to be increasing in inputs (i.e. monotonicity). This property requires that additional units of an input will non decrease output implying that all marginal products are non-negative[26]. To guarantee this property, an inequality restriction on parameters is imposed. The linear inequality restrictions are given by:

$$\beta_k = \sum_{m=1}^{5} z_{km} \tilde{p}_{km} \geq 0 , \qquad k = 1,\ldots, 5. \tag{18}$$

Additionally, linear homogeneity in inputs was imposed during estimation, requiring the following restriction on parameters to be satisfied:

$$\sum_k \beta_k = \sum_k \sum_{m=1}^{5} z_{km} p_{km} = 1 , \qquad k = 1,\ldots, 5. \tag{19}$$

The contemporaneous imposition of linear homogeneity in outputs and in inputs leads to the constant return to scale hypothesis which is a frequently maintained hypothesis for country level analysis. So it is assumed that at country level doubling all inputs results in exactly having twice as much output.

The final GME criterion, for the model including SI and NSI, maximizes the cumulative joint entropy representing the parameters ($\alpha_0, \alpha_g, \alpha_{gh}, \beta_k$), the stochastic error

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[25] Since the NSI2 restriction constitutes ratios involving two variables, only the strictly independent relationships had to be introduced via equation (15).

[26] This requires the production function to be continuously differentiable.

term e_i defined under (9), and the stochastic error associated with the NSI introduced during estimation. So that with $\mathbf{w}_{NSI} = (w_{NSI1/n,i}, w_{NSI2/n,i})$ the final GME criterion is given by

$$\max_{p,w,w_{NSI}} H(\mathbf{p},\mathbf{w},\mathbf{w}_{NSI}) = -\mathbf{p}'\ln\mathbf{p} - \mathbf{w}'\ln\mathbf{w} - \mathbf{w}_{NSI}'\ln\mathbf{w}_{NSI} \tag{20}$$

Subject to the moment or consistency constraint as given by equation (10), the GME adding-up conditions and the constraints (14), (16), (18) and (19) including output homogeneity and symmetry conditions. The primal solution to the GME problem including NSI are recovered by solving the first order Lagrangian conditions as explained above in the text. The model was estimated using the GAMS (Generalised Algebraic Modelling System) software, selecting the PATHNLP solver, which is a non-linear optimisation solver, see Brooke, Kendrick, Meeraus, Raman and Rosenthal (1998).

3.6 The results

As the aim of the paper was to provide further insights into how the output mix composition in agriculture changed after transition in Hungary and Poland, the output production and price patterns from the data are described in Table 3.1. . The average annual growth rates presented in Table 3.1 are computed by constructing logarithmic growth rates per year, $d\ln y_g / dt = \ln(y_{gt}/y_{gt-1})$. The yearly rates are then averaged across the relevant sub-periods. The percent average annual growth rate can be derived by simply multiplying by hundred the average annual growth rates presented in the top of Table 3.1. In the first half of the1990s there was a substantial decline in output. In the second half of the 1990s there was a period of recovery in output. As a consequence of that, the decade following transition typically shows a U-shaped output curve (Blanchard (1998: 1-24)). Therefore average annual growth rates in Table 3.1 are presented for two sub-periods 1991-1995, 1996-2001, and for the full sample 1991-2001.

In Hungary during the 1991-1995 period there was an average decline in the milk/beef/veal output (y_l) of about 9 percent per year (p.a.). The average annual growth rates of agricultural outputs shows that post-reform and after the period of uncertainty that followed transition most of the agricultural outputs declined. Focusing on quantities during 1991-95, the majority of agricultural outputs, particularly in Hungary, showed negative annual growth rates, see Table 3.1; y_{por} declined with a 11.9 percent (p.a.) in Hungary; y_l declined with a 7.8 percent p.a. in Poland. During 1996-01, y_l, y_{chi}, and y_{cer} increased for Hungary, whereas only y_{chi} increased for Poland. The only output that increases over the whole period 1991-01 was y_{chi}; its average annual growth rate was 1.2 percent in Hungary and 7.9 percent in Poland. According to OECD (2005: 77), the demand for poultry meat has nearly doubled in the last decade in the new member states. Poultry production is expected to further increase because of favourable production and positive investment conditions. Consumption is also expected to increase due to rising household income.

Table 3.1 Average logarithmic growth rates per year of agricultural outputs and prices

			Hungary			
Quantities	y_1	y_{chi}	y_{por}	y_{cer}	y_{pot}	y_{sug}
1991-2001	-0.0315	0.0122	-0.0515	-0.0006	-0.0215	-0.0704
1991-1995	-0.0902	0.0247	-0.1189	-0.0764	-0.0061	-0.0836
1996-2001	0.0077	0.0039	-0.0065	0.0500	-0.0318	-0.0615
Prices	p_1	p_{chi}	p_{por}	p_{cer}	p_{pot}	p_{sug}
1991-2001	0.1525	0.1036	0.1390	0.1204	0.0875	0.1388
1991-1995	0.1923	0.1624	0.2596	0.1605	0.2422	0.1791
1996-2001	0.1260	0.0700	0.0701	0.0937	-0.0009	0.1157
			Poland			
Quantities	y_1	y_{chi}	y_{por}	y_{cer}	y_{pot}	y_{sug}
1991-2001	-0.0333	0.0788	-0.0052	-0.0040	-0.0404	-0.0004
1991-1995	-0.0783	0.0246	0.0019	-0.0012	-0.0385	0.0384
1996-2001	-0.0032	0.1150	-0.0099	-0.0058	-0.0417	-0.0263
Prices	p_1	p_{chi}	p_{por}	p_{cer}	p_{pot}	p_{sug}
1991-2001	0.1930	0.1260	0.1338	0.1875	0.1678	0.1380
1991-1995	0.3582	0.2759	0.2434	0.3698	0.4960	0.3147
1996-2001	0.0829	0.0261	0.0608	0.0659	-0.0198	0.0371

Source: Authors' estimations based on FAO (2005).

Turning to the price patters presented in the bottom of Table 3.1, it shows that in the last decade agricultural output prices increased both in Hungary and Poland with the exception for potatoes in the second half of the 1990s. The price increase from the computed growth rates was large as compared to the logarithmic growth rates computed for the agricultural outputs. The price of chicken meat (p_{chi}) increased by 10 and 13 percent respectively for Hungary and Poland during 1991-2001. The chicken price increase is likely to have induced an increase in chicken meat (y_{chi}), which was still growing by 1 and 8 percent p.a. for Hungary and Poland respectively (see bottom of Table 3.1). The only price decline was found for potatoes during 1996-2001 for both countries.

The model estimates are discussed in Table 3.2 which shows the coefficients for the output distance function estimated by exploiting both SI and NSI. Statistical testing of model parameters is not useful here, since the problem at hand has limited degrees of freedom. A possibility could have been to rely on the so called normalized entropy measure (Golan, Judge and Miller (1996: 69)). However by having selected broad parameter support in order to attribute as much as possible weight to the data instead of to the entropy supports would have likely provided uninformative normalized entropy measures (i.e. uniformly distributed parameter probabilities). The estimated models, including SI and NSI, reported a good within sample predictive power. By computing the first order correlation between observed and predicted values it was found a correlation coefficient of 0.918 and 0.864 respectively for Hungary and Poland.

Table 3.2 Estimates of agricultural output distance function

Parameter	Hungary	Poland
α_0	0.0005	-0.1132
α_{chi}	-0.0503	-0.0445
α_{por}	-0.1917	-0.2198
α_{cer}	-0.2550	-0.2121
α_{pot}	-0.0561	-0.1565
α_{sug}	-0.0419	-0.0498
$\alpha_{chi,chi}$	-0.0217	-0.0285
$\alpha_{por.por}$	0.1813	0.0211
$\alpha_{cer,cer}$	-0.0599	-0.0290
$\alpha_{pot,pot}$	0.0103	0.0121
$\alpha_{sug,sug}$	-0.0322	-0.0305
$\alpha_{chi,por}$	0.0632	0.0309
$\alpha_{chi,cer}$	0.0052	-0.0011
$\alpha_{chi,pot}$	0.0072	0.0060
$\alpha_{chi,sug}$	0.0011	0.0150
$\alpha_{por,cer}$	0.0018	-0.0357
$\alpha_{por,pot}$	0.0121	0.0312
$\alpha_{por,sug}$	-0.0022	0.0183
$\alpha_{cer,pot}$	0.0996	0.0375
$\alpha_{cer,sug}$	0.0033	0.0083
$\alpha_{pot,sug}$	0.0217	-0.0197
β_{fer}	0.0056	0.0479
β_{lab}	0.0000	0.0000
β_{lan}	0.0000	0.7630
β_{liv}	0.6074	0.1892
β_{mac}	0.3870	0.0000
Entropy Value	191.2877	201.1009

Source: Authors' estimations.

The parameter estimates of the translog distance function are generally not directly interpretable, since production measures (i.e. responses, elasticities) are a combination of parameters and data. However from the output cross-coefficients it is possible to directly recover insights about the underlying output relationships. For an output oriented distance function, positive cross-terms (i.e. $\alpha_{gh} > 0$) indicate a smaller contribution of output y_h to overall production from increases in the y_g output variable (recall section 3.2). For example, the positive sign on the cross term on y_{chi} and y_{por} (i.e. $\alpha_{chi,por}$ coefficient) suggests that with larger amounts of pork there is a tendency for the production of chicken to decrease (in terms of their proportion of total agricultural output) *vis-à-vis* milk/beef/veal which is the numéraire output. The estimates show null coefficients for several input coefficients (see for example the coefficient for labour (β_{lab}) in Table 3.2). This is a consequence of poor data signals and the monotonicity condition enforcing the parameters to be non-negative.

Table 3.3 presents the estimated distance function-based output elasticities as we have seen before (section 3.2) they reflect contribution to production. The greatest productive contribution in Hungary and Poland comes from the production of milk/beef/veal (see $\varepsilon_{Do,1}$ in Table 3.3) where the contribution to production is 43 and 34 percent in the output share of Hungary and Poland respectively. In the estimated model the input contributions to production (see section 3.2) could be directly assessed from the estimated input coefficients because no second order terms were estimated. For Hungary, for example, after all NSI had been imposed, the inputs of fertilisers, livestock, and machinery appeared to be relevant, with the greatest contribution coming from livestock with β_{liv} = 0.607. In this case a 1 percent increase in livestock leads to a 0.6 percent increase in production.

Table 3.3 Distance function-based output elasticity estimates at sample average

	Hungary					
	$\varepsilon_{Do,1}$	$\varepsilon_{Do,chi}$	$\varepsilon_{Do,por}$	$\varepsilon_{Do,cer}$	$\varepsilon_{Do,pot}$	$\varepsilon_{Do,sug}$
1991-2001	0.4360	0.0623	0.1852	0.2325	0.0576	0.0265
1991-1995	0.4102	0.0611	0.1938	0.2323	0.0746	0.0281
1996-2001	0.4574	0.0633	0.1781	0.2326	0.0434	0.0251
	Poland					
1991-2001	0.3425	0.0463	0.1941	0.2188	0.1484	0.0499
1991-1995	0.3352	0.0403	0.2042	0.2127	0.1534	0.0541
1996-2001	0.3486	0.0512	0.1857	0.2238	0.1442	0.0464

Source: Authors' estimations.

From Table 3.3, it is also possible to see how the estimated distance function-based output elasticities evolved for the different periods considered in this analysis. In both countries, during 1991-1995, milk/beef/veal contributed less to overall agricultural production than in the period 1996-2001 (see the estimates for $\varepsilon_{Do,1}$). This is in accordance with the average annual decline rates presented in Table 3.1 for milk/beef/veal for the period 1991-1995. There is empirical evidence in Tonini and Jongeneel (2006) showing that livestock production was among all agricultural productions one of the most damaged outputs after transition. There is evidence for an increase in the contribution of chicken meat (i.e. $\varepsilon_{Do,chi}$) over time, which is expected given the positive growth rates found in Table 3.1. The rise of chicken meat was accompanied by a corresponding decline in the productive contribution of pork, potatoes and sugar beet in the second half of the 1990s.

In order to provide further insights on how the output mix composition changed after transition two measures were calculated. Firstly a normalized MRT was derived (i.e. a first order measure). Secondly output substitution Morishima elasticities were computed (i.e. a second order measure). Both measures further characterise the PPC as discussed in section 3.2. As indicated previously, the MRT varies with the choice of the output ratio (see also Appendix 3.1). Therefore a more interpretable measure is the MRT, normalized by the relative output ratio (see equation (2)). The top of Table 3.4 presents the normalized MRT measures, $MRT_{g,h} / (y_h / y_g) = sub_{g,h} = (r_g^* / r_h^*) / y_h / y_g$, for all the relevant output combinations during the two sub-periods 1991-1995, 1996-2001 as well as for the overall period 1991-2001.

Given the previously noted growth in chicken production, it is interesting to look to the tradeoffs between chicken and other outputs. Substitutability is most evident when moving away from chicken meat. This suggests that for the given technology further increases in chicken meat to the detriment of other outputs will be more difficult. More precisely, for Hungary during 1991-2001, it appears that shifts away from chicken toward pork ($sub_{chi,por} < 1$) are relatively easy. In a similar way by taking the reciprocal of $sub_{chi,por}$ it appears difficult to shift away from pork to chicken (i.e. $(1/sub_{chi,por}) = sub_{por,chi} > 1$). For Poland ease on movements on the PPC are found shifting away from chicken towards potatoes.

Table 3.4 Normalised marginal rates of transformation (MRT) and empirical revenue ratios

	Hungary			Poland		
	1991-2001	1991-1995	1996-2001	1991-2001	1991-1995	1996-2001
$Sub_{1,chi}$	7.0013	6.7185	7.2287	7.4029	8.3129	6.8060
$Sub_{1,por}$	2.3537	2.1170	2.5682	1.7646	1.6415	1.8774
$Sub_{1,cer}$	1.8753	1.7655	1.9666	1.5656	1.5756	1.5578
$Sub_{1,pot}$	7.5702	5.4985	10.5367	2.3084	2.1851	2.4176
$Sub_{1,sug}$	16.4626	14.5958	18.2022	6.8583	6.1902	7.5075
$sub_{chi,por}$	0.3362	0.3151	0.3553	0.2384	0.1975	0.2758
$sub_{chi,cer}$	0.2678	0.2628	0.2721	0.2115	0.1895	0.2289
$sub_{chi,pot}$	1.0813	0.8184	1.4576	0.3118	0.2629	0.3552
$sub_{chi,sug}$	2.3514	2.1725	2.5180	0.9264	0.7446	1.1031
$sub_{por,cer}$	0.7967	0.8340	0.7658	0.8873	0.9599	0.8297
$sub_{por,pot}$	3.2164	2.5973	4.1028	1.3082	1.3312	1.2878
$sub_{por,sug}$	6.9945	6.8945	7.0876	3.8867	3.7711	3.9989
$sub_{cer,pot}$	4.0369	3.1144	5.3578	1.4744	1.3868	1.5520
$sub_{cer,sug}$	8.7788	8.2672	9.2555	4.3805	3.9287	4.8195
$sub_{pot,sug}$	2.1747	2.6545	1.7275	2.9710	2.8329	3.1053
$(p.y)_1/(p.y)_{chi}$	2.1808	2.2185	2.1494	5.7085	6.6593	4.9163
$(p.y)_1/(p.y)_{por}$	0.7106	0.6679	0.7463	1.1386	0.9748	1.2750
$(p.y)_1/(p.y)_{cer}$	0.5094	0.5440	0.4806	1.0385	1.1114	0.9777
$(p.y)_1/(p.y)_{pot}$	3.9519	3.1619	4.6102	1.8833	1.7892	1.9617
$(p.y)_1/(p.y)_{sug}$	7.4794	7.2740	7.6505	7.2158	7.2886	7.1551
$(p.y)_{chi}/(p.y)_{por}$	0.3303	0.3068	0.3500	0.2099	0.1490	0.2606
$(p.y)_{chi}/(p.y)_{cer}$	0.2352	0.2486	0.2240	0.1862	0.1697	0.2000
$(p.y)_{chi}/(p.y)_{pot}$	1.8445	1.4363	2.1847	0.3466	0.2790	0.4029
$(p.y)_{chi}/(p.y)_{sug}$	3.4035	3.3026	3.4877	1.3143	1.1256	1.4716
$(p.y)_{por}/(p.y)_{cer}$	0.7181	0.8151	0.6373	0.9400	1.1509	0.7643
$(p.y)_{por}/(p.y)_{pot}$	5.5715	4.7004	6.2974	1.6960	1.8686	1.5522
$(p.y)_{por}/(p.y)_{sug}$	10.3564	10.7996	9.9870	6.4855	7.5614	5.5888
$(p.y)_{cer}/(p.y)_{pot}$	8.1340	5.8944	10.0003	1.8543	1.6379	2.0346
$(p.y)_{cer}/(p.y)_{sug}$	14.4376	13.0559	15.5889	6.9839	6.6173	7.2894
$(p.y)_{pot}/(p.y)_{sug}$	1.9589	2.3100	1.6663	3.9807	4.3360	3.6847

Source: Authors' estimations.

By looking at the sub-samples 1991-1995 and 1996-2001, there is a change in the ease of shift for Poland when moving away from chicken meat towards sugar beets; for 1991-1995 it is relatively easy to move away from chicken towards sugar beets (i.e. $sub_{chi,sug}<1$), for 1996-2001 it is relatively difficult (i.e. $sub_{chi,sug}>1$). Turning to the interpretation of the normalized MRT over time, it appears that facility in movements along the PPC associated with the output pairs presented in Table 3.4 is declining over time. However this is only partial information contextual to the output pairs which are considered. Results would be reverted when considering the reciprocal of the normalized MRT presented in the top of Table 3.4.

By comparing the estimated $sub_{g,h} = \left(r_g^* y_g / r_h^* y_h\right)$ elasticities with the calculated revenue ratios $p_g y_g / p_h y_h$ (see bottom part of Table 3.4), it is possible to get insight into allocative inefficiency in the output mix. The larger the discrepancies between the two measures become, the greater the adjustment costs are indicating differences among the estimated shadow output valuations and the observed market revenue ratios. Discrepancies may be attributed in this context to imperfect knowledge (i.e. asymmetric knowledge in land contracting in Eastern Europe), resource immobility (typical for the agricultural sector), and insufficient production (see the output decline described above). First by computing the squared deviations between the two measures presented in Table 3.4, it appears that discrepancies are higher for Hungary than for Poland. This indicates that allocative inefficiencies are greater for Hungary than for Poland. Second, allocative inefficiencies increase over time for Hungary but decrease over time for Poland. These last two findings could be correlated to the level of support to producers which in the last decade increased for Hungary and decreased for Poland. In the first half of the 1990s, the level of support to producers, as measured by the percentage producer support equivalent (PSE) computed by OECD, increased in all new member states except Poland (OECD (2005: 83)). Between 1995 and 2003 the percentage PSE increased from 13 to 28 percent for Hungary whereas for Poland it decreased from 16 to 8 percent.

Looking at single commodities and comparing top and bottom parts of Table 3.4, it shows large discrepancies particularly for ratios associated with sugar beet both for Hungary and Poland. For Hungary, the estimated valuation (or contribution to output) of y_{sug} is large relative to its market price in three cases out of five (see the measure presented in Table 3.4 for the following pairs: y_{chi}-y_{sug}, y_{por}-y_{sug}, and y_{cer}-y_{sug}). This indicates adjustment costs associated with sugar beets reflecting overspecialization in sugar beets for Hungary and Poland. Similar findings were also obtained for potatoes (y_{pot}), where the estimated valuation of y_{pot} is also large relative to its market price in most of the cases. Conversely small discrepancies were found for ratios associated with chicken meat (y_{chi}). This means that although chicken trend were increasing as well as its shadow valuation, its production was in line with market conditions. This situation can be also connected with a rising demand for white meats in Eastern Europe.

Table 3.5 Morishima output substitution elasticities

	Hungary			Poland		
	1991-2001	1991-1995	1996-2001	1991-2001	1991-1995	1996-2001
$M_{1,chi}$	2.0411	2.1314	1.9726	0.8524	0.9318	0.7992
$M_{1,por}$	2.5395	2.5513	2.5404	0.7078	0.6991	0.7166
$M_{1,cer}$	1.3710	1.4439	1.3166	0.2780	0.2835	0.2736
$M_{1,pot}$	3.7761	3.2513	4.5772	0.8209	0.8143	0.8276
$M_{1,sug}$	0.8422	0.9329	0.7710	0.1974	0.2188	0.1780
$M_{chi,1}$	-0.2219	-0.2209	-0.2223	-0.5497	-0.6390	-0.4914
$M_{chi,por}$	-0.6897	-0.6817	-0.6978	-0.7741	-0.8569	-0.7218
$M_{chi,cer}$	-0.3709	-0.3778	-0.3653	-0.6101	-0.7006	-0.5507
$M_{chi,pot}$	-0.4739	-0.4522	-0.5092	-0.6554	-0.7448	-0.5971
$M_{chi,sug}$	-0.3899	-0.3945	-0.3866	-0.9153	-0.9827	-0.8785
$M_{por,1}$	1.5667	1.5606	1.5781	0.3004	0.2992	0.3019
$M_{por,chi}$	-0.0366	-0.1000	0.0187	-0.5588	-0.6626	-0.4893
$M_{por,cer}$	0.9711	0.9280	1.0102	0.2719	0.2712	0.2732
$M_{por,pot}$	0.7691	0.7739	0.7397	-0.1014	-0.0999	-0.1026
$M_{por,sug}$	1.0609	1.0131	1.1043	-0.2581	-0.2350	-0.2808
$M_{cer,1}$	-0.1431	-0.1360	-0.1483	-0.1907	-0.1958	-0.1867
$M_{cer,chi}$	-0.3419	-0.3437	-0.3404	-0.1092	-0.1095	-0.1085
$M_{cer,por}$	-0.2675	-0.2672	-0.2678	0.0517	0.0388	0.0630
$M_{cer,pot}$	-1.9872	-1.5930	-2.5517	-0.3850	-0.3805	-0.3893
$M_{cer,sug}$	-0.3811	-0.3741	-0.3876	-0.2990	-0.2898	-0.3086
$M_{pot,1}$	0.5254	0.5063	0.5676	0.2769	0.2786	0.2759
$M_{pot,chi}$	0.0632	0.0200	0.1236	-0.0484	-0.0702	-0.0335
$M_{pot,por}$	0.1140	0.0760	0.1700	-0.0792	-0.0740	-0.0842
$M_{pot,cer}$	-0.2492	-0.2903	-0.1904	-0.0900	-0.0975	-0.0838
$M_{pot,sug}$	-0.6386	-0.6323	-0.6240	0.4755	0.4422	0.5076
$M_{sug,1}$	-1.2337	-1.1649	-1.2981	-0.6363	-0.5894	-0.6820
$M_{sug,chi}$	-1.2324	-1.1627	-1.2973	-0.9354	-0.9358	-0.9502
$M_{sug,por}$	-1.2030	-1.1334	-1.2678	-0.7056	-0.6534	-0.7560
$M_{sug,cer}$	-1.2287	-1.1587	-1.2940	-0.6492	-0.6028	-0.6945
$M_{sug,pot}$	-1.5908	-1.4350	-1.7788	-0.4785	-0.4354	-0.5208

Source: Authors' estimations.

In addition to first order substitutability measures second order substitutability measures in the form of Morishima elasticities were also derived (see equation (3) in the text). Table 3.5 reports the Morishima substitution elasticities for the estimated distance functions. If the Morishima elasticity $M_{g,h}$ is greater than zero (smaller than zero), output y_h is said to be Morishima substitute (Morishima complement) for output y_g. Out of all output pair combination it appears that most of Morishima elasticities are negative indicating a limited amount of substitutability and a predominance of complementarity relationships, which can be expected using rather aggregated data. The differences in magnitude of the Morishima substitution elasticities across the different sub-samples are less remarkable than the differences encountered for the normalized MRT's presented in Table 3.4. Focusing on complementarity relationships across the two sub-samples, for Hungary in most of the cases the degree of complementarity increases. Moving to substitutability relationships, there is a tendency for an increase in substitutability in the second half of the 1990s both for Hungary and for Poland.

3.7 Concluding remarks

This paper represents a first effort to analyze the agricultural output substitutability and allocative inefficiencies of Hungary and Poland after transition. The focus was on analyzing to what extent the composition of agricultural outputs changed after reform and to measure the degree of allocative inefficiencies in the output mix. Time series data for the period 1991-2001 were constructed using aggregate data on agricultural production.

An output distance function was estimated because it allowed treating multi-output technologies as compared to traditional single output production function approaches. The novelty of the approach used in this paper was in exploiting additional source of information external to sample data. More precisely a set of stochastic economic restrictions based on the duality theory of production were introduced during estimation as constraints. First a set of restrictions coming from prior beliefs on the output distance function elasticities was elaborated. Second a set of restrictions imposed a "mild" revenue maximization behavioural condition. Finally a set of restrictions made sure that the estimated technology was non-decreasing in inputs and satisfied the constant return to scale hypothesis.

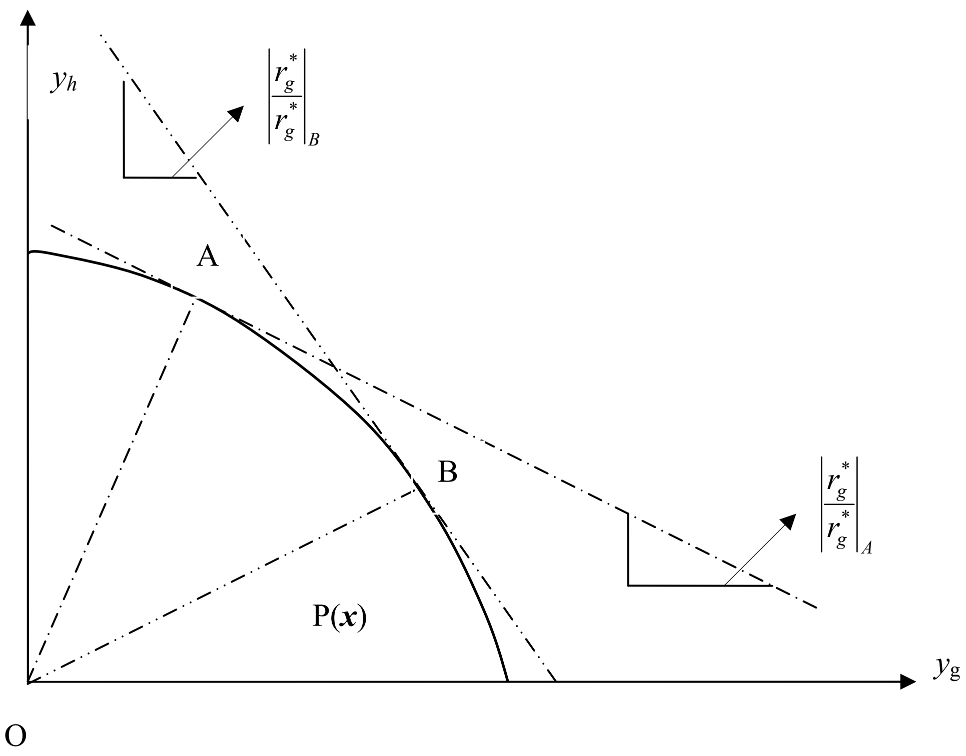
After transition, the agricultural output mix was largely influenced. Post-reform in the first half of the 1990s, the majority of agricultural outputs declined, especially milk and beef and veal production. Output prices showed large growth rates in the last decade with the only exception made for potatoes, which had also a declining trend in terms of quantity. From the estimated models it appeared that in the second half of the 1990s the productive contribution of dairy and chicken meat increased whereas pork, potatoes, and sugar beets declined. Given favourable market condition and an increasing demand for white meat, chicken meat is expected to further increase in the coming years. By inspecting the normalized MRT movements away from chicken towards other agricultural products appeared to be relatively easy. At the same time this indicates that given the available technology characterizing the agriculture of Hungary and Poland it is going to be more difficult to increase chicken getting rid of the other agricultural products.

Adjustment costs were greater and increasing over time for Hungary as compared to Poland. This could be partly explained by the relatively high and increasing level of producer support in Hungary which may have introduced market distortions as compared to Poland. Adjustment costs were relevant particularly for sugar beets indicating overspecialization for sugar beet. Conversely the shadow valuation of chicken meat was in line with market valuation. However this situation may change if further increases on chicken meat production will not be justified by price increases. Second order substitutability measures indicated an increase in the degree of complementarity and substitutability in the second half of the 1990s. This indicates that the production relationships related to the curvature of the multi-output technology further consolidated in the second half on the 1990s as compared to the period immediately following the reform.

Appendix 3.1

The MRT for an output based distance function

The model section 3.2 discussed the marginal rate of transformation (MRT) for an output oriented distance function. The MRT is not an invariant measure to the observed output mix. This Appendix, explains the use of an alternative measure as proposed by Grosskopf, Margaritis and Valdmanis (1995). Let us make several simplifying assumptions. First consider an output distance function where only two observed outputs are available (y_h and y_g). Second assume that technical inefficiency is absent so that observations lie on the PPC. The PPC is presented in Figure A3.1 for two outputs *g* and *h*.



Source: Adapted from Grosskopf, Margaritis and Valdmanis (1995: 579)

Figure A3.1 Output shadow prices for an output distance function

In Figure A3.1, *P*(***x***) is the technological output set representing all feasible combination of output ***y*** given an input vector ***x***. Since in this simplified example the possible output combination (i.e. output mix) lies on the surface of the output set (i.e. no technical inefficiencies), it is only possible to envisage movements along the PPC. As described in the model Section 3.2, the output shadow prices can be recovered for an output distance function from the dual Shepard's Lemma, as given by:

$$\left(\partial D_o(\boldsymbol{x},\boldsymbol{y})/\partial y_g\right) = r_g^*(\boldsymbol{x},\boldsymbol{y}), \qquad g = 1,\ldots,G, \tag{I.1}$$

where $D_o(\boldsymbol{x},\boldsymbol{y})$ indicates the output oriented distance function, and $\boldsymbol{x}$ and $\boldsymbol{y}$ are respectively the input and output vectors and $r_g^*(\boldsymbol{x},\boldsymbol{y})$ denotes the revenue-deflated support or shadow price of output *g*. The shadow prices give an indication of the valuation of the output in terms of its contribution to overall output (Morrison-Paul, Johnston and Frengley (2002: 331)). The ratio of these output shadow prices gives MRT between two outputs. The MRT represents the slope of the PPC between two outputs as given in Figure A3.1. The MRT for two outputs *g* and *h* can be decomposed in:

$$MRT_{g,h} = \left(r_g^*(\boldsymbol{x},\boldsymbol{y})/r_h^*(\boldsymbol{x},\boldsymbol{y})\right) = \frac{\partial D_o(\boldsymbol{x},\boldsymbol{y})/\partial y_g}{\partial D_o(\boldsymbol{x},\boldsymbol{y})/\partial y_h} =$$

$$= \frac{\left(\partial \ln D_o/\partial \ln y_g\right)}{\left(\partial \ln D_o/\partial \ln y_h\right)} \cdot \frac{\left(D_o/y_g\right)}{\left(D_o/y_h\right)} = \frac{\left(\partial \ln D_o/\partial \ln y_g\right)}{\left(\partial \ln D_o/\partial \ln y_h\right)} \cdot \frac{y_h}{y_g} \tag{I.2}$$

Note that the PPC, when moving from A to B (see Figure A3.1), will have an increasing output shadow price ratio $r_g^*(\boldsymbol{x},\boldsymbol{y})/r_h^*(\boldsymbol{x},\boldsymbol{y})$ as the output ratio y_h/y_g diminishes. This is consistent with traditional production theory according to which the increased production of one output can only occur at an increasing opportunity cost (i.e. increasing marginal rate of transformation).

In order to derive a measure independent from the observed output mix, (Grosskopf, Margaritis and Valdmanis (1995)) have proposed to normalize the output shadow price ratio by the observed output mix. In this way a new and invariant output substitutability measure is obtained as follows:

$$sub_{gh} = MRT_{g,h} \cdot \frac{y_g}{y_h} = \frac{\left(\partial \ln D_o/\partial \ln y_g\right)}{\left(\partial \ln D_o/\partial \ln y_h\right)} = \frac{\varepsilon_{D_{0,g}}}{\varepsilon_{D_{0,h}}} \tag{I.3}$$

In this way the normalized MRT (i.e. sub_{gh}) is nothing more than the ratio of the output distance function elasticities.

Appendix 3.2

Descriptive statistics

	Hungary		Poland	
	Mean	S.D.	Mean	S.D.
Milk/beef/veal	0.7706	0.1084	0.7951	0.0831
Chicken meat	1.0649	0.0806	1.3985	0.4402
Pork	0.7006	0.1184	0.9956	0.0568
Cereals	0.7869	0.1359	0.9044	0.0934
Potatoes	0.9692	0.1216	0.8582	0.1656
Sugar beets	0.5902	0.1913	1.1872	0.1982
Fertilisers	1.1277	0.2518	1.3020	0.1642
Labour	0.9497	0.0247	0.9852	0.0108
Land	0.8488	0.0967	0.9206	0.0540
Livestock	0.6751	0.1270	0.8437	0.0862
Machinery	1.0444	0.0929	1.0783	0.0560

Source: Authors' calculations based on FAO (2005).

CHAPTER 4

Modelling the dairy and beef supplies for Hungary and Poland using a mixed generalised maximum entropy estimator

Abstract

This paper develops a unique and innovative quantitative approach to modelling dairy and beef supplies for transformation countries, which is then applied to Hungary and Poland. Relying on generalised maximum entropy formalism, we provide a useful empirical basis for treating ill-posed and ill-conditioned problems by reconciling sample information and non-sample information. Moreover, adjustments in variable as well as quasi-fixed factors are taken into account. Our results suggest overall an inelastic dairy supply response for Hungary and Poland. In addition, we found complementarity between the productions of milk and beef in the medium run, when dairy cow stock can be adjusted.

Tonini, A., R. Jongeneel. Modelling the dairy and beef supplies for Hungary and Poland using a mixed generalised maximum entropy estimator. Submitted for publication in the *European Review of Agricultural Economics*. This work strongly benefited from my participation in the European Dairy Industry Model (EDIM) project. See in particular JONGENEEL, R., and A. TONINI (2005): "A Mixed Generalized Maximum Entropy Approach: Modeling the Primary Dairy Sectors of Czech Republic, Hungary, Lithuania and Poland," Working Paper: 06/2005, EDIM, Wageningen: Wageningen University, 43 and JONGENEEL, R. (2005): "Report on Modeling Milk and Dairy Industry in the New Member States," Deliverable: D06.03, EDIM, Wageningen: Wageningen University, 63.

4.1 Introduction

Hungary and Poland are respectively the fourth and first dairy milk producers among the eight Central Eastern European Countries (CEECs) that joined the European Union (EU) in May 2004. Their milk production in 2005 was 2.0 million tons of milk for Hungary and 12.4 million tons for Poland. Their exports of whole milk in 2002 were 0.2 million tons for Hungary and 1.1 million tons for Poland, making them second and first exporters respectively in the eight CEECs (FAO (2005)).

Both countries have experienced tremendous changes over the last fifteen years, the most important being the so-called transition reform in the 1990s and the accession to the EU in 2004. The transition reform process liberalised prices by removing subsidies for production and consumption. Farmers were suddenly exposed to a change in the economic environment: a move from a highly distorted and subsidised system to a more market-oriented system. As a result of the worsened terms of trade following the economic reform, the supply of many agricultural products – particularly dairy products – diminished (Macours and Swinnen (2000: 172-176), Rozelle and Swinnen (2004: 407-418)).

In 2004 the accession to the EU required the New Member States (NMS) to gradually take on board the Common Agricultural Policy (CAP) framework. The most important changes for the enlarged EU dairy sector included domestic policy reforms and the World Trade Organisation (WTO) round of negotiations. As a result of the domestic policies embedded in the Luxembourg Reform, the support prices for butter and skimmed milk powder had to drop, the milk quota system was retained and payments were decoupled. The WTO commitments demanded a further reduction in trade barriers. The next reform in the EU dairy policy is due in 2008 (Fischer Boel (2006)).

Given the trends described above, there is clearly a need to provide quantitative information on the dairy and beef supply response to price for policy analysis in transition economies (Petit and Brooks (1994: 486-491)). Most models that consider the dairy sector for the CEECs are static in nature and based on calibrated elasticities (Swenning (1999), Wahl, Weber and Frohberg (2000), Mergos (2002), Jensen and Frandsen (2003), FAPRI (2004), Ledebur and Manegold (2004), Banse and Grethe (2005), Grethe and Weber (2005), among others). Hence they are unable to satisfactorily capture the post-reform adjustment process in the outputs and inputs. Significant adjustments to the changed terms of trade have been observed after transition, particularly with respect to livestock (Tonini and Jongeneel (2006)).

In addition, the elasticities on which the PE models are calibrated are mostly experts' "guesstimates" that lack empirical support.

The lack of empirical estimates of supply response is largely due to shortcomings in the quantity and quality of official statistics (Blangiewicz, Bolt and Charemza (1993)). The statistics available for the period prior to the 1990s relate to political, economic and institutional systems that have since been superseded in the current new market-oriented economy. It therefore makes no sense to rely on pre-transition data, since not only has the way the data were generated changed, but so has the system they are intended to describe (Hallam (1998: 125)). Furthermore, sole reliance on data post-dating the transition reform makes it difficult to use traditional econometric techniques, because the data series are too short.

The aim of this paper is to develop a unique and innovative empirical framework able to cope with severe data limitations and thus allowing for empirical estimation of the supply response of agriculture in transition economies. The objective is to provide first empirical estimates of the dairy and beef supplies for Hungary and Poland. A central issue concerning this process is the selection of an appropriate estimation technique. One possibility for overcoming the lack of sufficient data is to reconcile sample data with external sources of information (Judge, Griffiths, Hill, Lütkepohl and Lee (1985: 54-108), Griffiths, Hill and Judge (1993: 369-408), Greene (2000: 408)). Agricultural economists always have some prior expectations about the parameter sign – and in some cases even about the parameter range – of plausible values for a set of parameters to be estimated. The expectations may be based on previous research, economic theory, the characteristics of the environment modelled, or researcher introspection.

There is a long history of using non-sample information (NSI) in econometrics. Such information has been used to solve ill-posed and ill-conditioned problems[27] since the work of Durbin (1953), in which extraneous information about one of the regression coefficients was incorporated during estimation. The possibility of combining sample information (SI) with NSI was then formalised in the Theil–Goldberger mixed estimation (TGME) procedure (Theil and Goldberger (1961), Theil (1963)). The mean-square-error-reducing property made the TGME an attractive approach for solving a broad range of problems such as the effect of

[27] Paris and Howitt (1998: 124) distinguish between ill-posed and ill-conditioned data issues. The former refers to the case when there are fewer observations than the parameters to be estimated. The latter refers to the case when parameter estimates have low accuracy and are unstable as a result of multicollinearity problems.

multicollinearity, the introduction of Shiller's smoothness priors in distributed lag models, and the ridge regression procedure. For a survey on the theory of mixed estimation in econometrics, see Toutenburg (1982) and Conway and Mittelhammer (1986). At the end of the 1980s, the appropriateness of the TGME procedure was questioned, because of its lack of a well-established estimation criterion. It was Mittelhammer and Conway (1988) who rationalised the TGME criterion by obtaining the prior introspective estimator that relies on random number generation procedures. In this way they proved that the TGME is quadratic-risk inadmissible; to replace it, they introduced the prior integrated mixed estimator.

Other alternative techniques allowing for NSI to be incorporated during the estimation are the Bayesian (Zellner (1971), Koop (2003), Lancaster (2004)) and maximum entropy (ME) approaches (Golan, Judge and Miller (1996), Mittelhammer, Judge and Miller (2000)). The main difference between these two approaches is that ME does not need to pre-specify and regularise a likelihood function. However, both are based on probability statements about the unknown parameters to be estimated. They therefore contrast with the more traditional frequentist paradigm[28] in which the objective is to provide an estimate of the constant unknown parameters representing the underlying population, based solely on the sample data.

In our approach, SI and NSI are reconciled during estimation, relying on a generalised maximum entropy (GME) estimator. We exploit NSI in terms of required theoretical restrictions on parameters and restrictions originating from knowledge based on other economic and non-economic research. Because of issues of uncertainty and compatibility, the latter restrictions (which might be equality or inequality restrictions) are stochastic in nature. In this way we provide final parameter estimates that are close to the original sample data, largely consistent with economic theory, and that fit with the researcher's expectations. This approach allows maximum integration of all the available information.

The remainder of this paper is organised as follows. Section 2 develops the specification of the empirical model. Section 3 describes the estimation procedure based on SI and theoretical constraints. Section 4 develops the way in which NSI is included during the estimation procedure. Our results and conclusions are presented in sections 5 and 6 respectively.

[28] The frequentist paradigm refers to the behaviour of statistics in repeated samples.

4.2 Empirical specification

This section develops the empirical model specification. In the majority of the CEECs, beef production is a by-product of dairy production; from this it follows that the decisions about beef production depend on decisions about dairy production – and vice versa (EC (2002)). The theoretical model developed here, which is based on the duality theory of production (Diewert (1974), Beattie and Taylor (1985), Chambers (1988)), explicitly allows for jointness in outputs, and integrates dairy and beef productions. Dairy and beef productions are assumed to be produced using variable inputs and some quasi-fixed inputs.

A normalised restricted quadratic profit function is specified (Lau (1976)). It has been chosen because it is empirically elegant and remains flexible even when global convexity is imposed (Diewert and Wales (1987)). The behavioural objective consists of maximising profits on dairy and beef for given prices and quasi-fixed inputs. The normalised restricted quadratic profit function is specified as follows:

$$\pi_t^n = \alpha_0 + \sum_{i=1}^{2} \alpha_i n_{i,t}^n + \sum_{h=1}^{3} \beta_h f_{h,t} + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \alpha_{ij} n_{i,t}^n n_{j,t}^n + \frac{1}{2}\sum_{h=1}^{3}\sum_{k=1}^{3} \beta_{hk} f_{h,t} f_{k,t} + \sum_{i=1}^{2}\sum_{h=1}^{3} \gamma_{ih} n_{i,t}^n f_{h,t} \quad (1)$$

where $n_{i,t}^n\ (= n_{i,t}^0 / n_{I,t}^i)$ are output prices $\left(n_{i,t}^o\right)$ normalised by a feed price (i.e. variable input) index $\left(n_{I,t}^i\right)$ with i = 1 (milk), 2 (beef meats), 3 (animal feed). In addition, $f_{h,t}$ are quasi-fixed inputs and a trend with h = 1 (dairy cow stock), 2 (permanent pasture) and 3 (time trend). The parameters to estimate are $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, and $\boldsymbol{\gamma}$. Several regularity conditions have to be satisfied in order to meet the duality between profit and production functions. The conditions are linear homogeneity in prices, symmetry, monotonicity and convexity in prices.

The dairy and beef supply equations are derived by differentiating (1) with respect to the normalised prices of cow milk and beef $\left(n_{i,t}^n\right)$ (Hotelling's Lemma) (Beattie and Taylor (1985: 227))[29]:

[29] Several procedures are generally followed when estimating the system of equations constituted by equations (1) and (2) (Sadoulet and de Janvry (1995: 67-68)). One possibility is to jointly estimate the profit function and the derived output supplies and factor demands by increasing the efficiency of the parameters obtained. Another possibility is simply to estimate the set of output supplies and input demands. In this analysis the restricted profit function was not included during the estimation because of doubts about the reliability of the definition and quality of animal feed in our sample data. The computation of profits on the basis of observations may be sensitive to measurement errors in the figures (e.g. for amounts of animal feed) that result in inconsistent estimates. In addition, multicollinearity issues may increase because of the second order terms in the profit function, which exploits limited data. For similar reasons, the demand for animal feed (a variable input) was not estimated directly.

$$y_{i,t} = \alpha_i + \sum_{j=1}^{2} \alpha_{ij} n_{j,t}^{n} + \sum_{h=1}^{3} \gamma_{ih} f_{h,t} + e_{ti}, \qquad i = 1, 2. \qquad (2)$$

Of the four regularity conditions required, homogeneity in prices is embedded in the model specification through the use of normalised prices. Symmetry requires $\alpha_{ij} = \alpha_{ji}$ and $\beta_{hk} = \beta_{kh}$ for all *i* and *j*. Monotonicity and convexity of the profit function in prices requires that the own price elasticities of the output supplies in equation (2) be positive and that the Hessian matrix of price derivatives be positive semi-definite (Chiang (1984: 338-340)). The inequality restrictions for convexity in prices are:

$$\alpha_{11} \geq 0, \ \alpha_{22} \geq 0 \qquad (3\ a)$$

$$\alpha_{11} \cdot \alpha_{22} - \alpha_{12} \cdot \alpha_{21} \geq 0 \qquad (3\ b)$$

where α_{11}, α_{22} and α_{12} are coefficients associated respectively with the prices of milk, beef meat, and their cross-products. The first two inequalities (3 a) ensure that the own price elasticities of the output supplies are positive (i.e. monotonicity) and that the last inequality (3 b) ensures a positive semi-definite determinant for the Hessian matrix of second order derivative terms.

The optimal levels for the two quasi-fixed inputs can be obtained by differentiating the profit function equation (1) with respect to the quasi-fixed inputs (Moschini (1988: 320)) and rewriting this as

$$f_{h,t}^{*} = \frac{1}{\beta_{hh}} \left(n_{h,t}^{shadow} - \beta_h - \sum_{h \neq k}^{3} \beta_{hk} f_{k,t} - \sum_{i=1}^{2} \gamma_{ih} n_{i,t}^{n} \right) \qquad (4)$$

where $f_{h,t}^{*}$ represents the optimal level for the quasi-fixed input, and $n_{h,t}^{shadow}$ represents the associated shadow price. Since it is not the quasi-fixed factors which are optimised, there is no reason to expect the shadow prices to equal market prices. Although the quasi-fixed factor inputs will not adjust instantaneously, their adjustment is likely to be governed by the explanatory variables as given by (4). As an approximation, the demand for the quasi-fixed inputs is assumed to follow a partial adjustment scheme, in which the achieved level of the quasi-fixed inputs is a function of the level achieved one period lagged, plus a "correction" term based on the difference between lagged optimal and lagged achieved levels. The quasi-fixed factor input is given by

$$f_{h,t} = f_{h,t-1} + \lambda_h \left(f_{h,t-1}^{*} - f_{h,t-1} \right) = \lambda_h f_{h,t-1}^{*} + (1 - \lambda_h) f_{h,t-1} \qquad (5)$$

where $f_{h,t}$ is the actual quasi-fixed input level, $f^{*}_{h,t-1}$ is the optimal quasi-fixed input level one period lagged, and λ_h is a partial adjustment coefficient with $0 < \lambda_h < 1$ for *h* = 1, 2. Substituting (4) into (5) yields an equation explaining the actual level of the quasi-fixed factors as

$$f_{h,t} = \frac{\lambda_h}{\beta_{hh}}\left(n^{shadow}_{h,t} - \beta_h - \sum_{h \neq k}^{3} \beta_{hk} f_{k,t-1} - \sum_{i=1}^{2} \gamma_{ih} n^{n}_{i,t-1} \right) + \left(1 - \lambda_h\right) f_{h,t-1} + e_{th}\,,\ h = 1,\ 2. \qquad (6\ \text{a})$$

Equation (6) still contains an unobservable – the shadow price – which, in addition is probably correlated with other prices. For example, the value of a cow can be interpreted to be equal to the discounted flow of net revenue it generates during its lifetime, which clearly depends on the prices for milk, beef and feed. In order to preserve empirical tractability, therefore, as a second approximation the shadow price is dropped from (6 a), which gives

$$f_{h,t} = \frac{\lambda_h}{\beta_{hh}}\left(-\beta_h - \sum_{h \neq k}^{3} \beta_{hk} f_{k,t-1} - \sum_{i=1}^{2} \gamma_{ih} n^{n}_{i,t-1} \right) + \left(1 - \lambda_h\right) f_{h,t-1} + e_{th}\,, \qquad h = 1,\ 2. \qquad (6\ \text{b})$$

In this way, a system of four equations (see (2) and (6 b)) is derived, which is jointly estimated. The fact that in equation (6) the explanatory variables are lagged one period directly follows from the underlying partial adjustment scheme in equation (5 b) and at the same time decreases potential problems of simultaneity in the estimated system.

Short-run price elasticities can be computed at any point in time and are given by

$$\eta^{S}_{ij} = \frac{\partial y_{i,t}}{\partial n_{j,t}} \cdot \frac{n^{n}_{j,t}}{y_{i,t}} = \tilde{\alpha}_{ij} \cdot \frac{n^{n}_{j,t}}{y_{i,t}}\,, \qquad i, j \neq \mathrm{I}, \qquad \eta^{S}_{jI} = -\sum_{l} \eta_{jl} \qquad (7)$$

where $\tilde{\alpha}_{ij}$ are estimated parameters. Similarly, the elasticities of intensity indicating the relation between dairy and beef outputs and fixed inputs can be derived through

$$\kappa_{ih} = \frac{\partial y_{i,t}}{\partial f_{h,t}} \cdot \frac{f_{h,t}}{y_{i,t}} = \tilde{\gamma}_{ih} \cdot \frac{f_{h,t}}{y_{i,t}} \qquad (8)$$

where $\tilde{\gamma}_{ih}$ are estimated parameters. The elasticities can be calculated for various lengths of run (i.e. short, medium, and long runs) depending on which quasi-fixed inputs are allowed to adjust. Here we report the general expression for the medium-run own price elasticities

$$\eta^{M}_{ij} = \frac{\partial y_{i,t}}{\partial n_{j,t}} \cdot \frac{n^{n}_{j,t}}{y_{i,t}} + \frac{\partial y_{i,t}}{\partial f_{h,t}} \frac{\partial f_{h,t}}{\partial n^{n}_{j,t-1}} \cdot \frac{n^{n}_{j,t-1}}{y_{i,t}} = \tilde{\alpha}_{ij} \cdot \frac{\partial n^{n}_{j,t}}{y_{i,t}} - \tilde{\gamma}_{ii} \frac{\tilde{\lambda}_i}{\tilde{\beta}_{ii}} \tilde{\gamma}_{ii} \cdot \frac{n^{n}_{j,t-1}}{y_{i,t}} \qquad (9)$$

where $\tilde{\alpha}_{ij}$, $\tilde{\gamma}_{ii}$, $\tilde{\lambda}_i$ and $\tilde{\beta}_{ii}$ are estimated parameters and the lagged prices adjust to current prices in the medium run so that $n^{n}_{j,t} = n^{n}_{j,t-1}$.

4.3 Estimation

Data on Hungarian and Polish agriculture were obtained from mixed statistical sources based on FAO (2005), OECD (2004), and national statistical offices. Summary statistics are provided in the Appendix, see Table A4.1. The data cover the period 1990–2002 and are indexed to the base year 1990. For Poland, the milk originating from subsistence farming[30] is excluded from the national milk production (EC (2002b), Banse and Grethe (2005)). In order to take into account the farmers' response to expected prices, the output and variable input prices $\left(n_{i,t}^{o}, n_{I,t}^{i}\right)$ are expressed as a three-year moving average. The animal feed input price is computed by creating a feed price index based on the major coarse grain feed ingredients. For Hungary, since the series for permanent pasture between 1990 and 2002 did not show sufficient variation over time, use was made of the so-called productive agricultural land, which according to the definition of the Hungarian national statistical office (KSH) also includes the area of arable land[31].

The estimation technique used in this analysis is based on the ME approach, which is based on the entropy-information measure of Shannon (1948). Shannon used entropy methods to measure the state of knowledge (uncertainty) we have about the occurrence of a set of events. Others (Golan, Judge and Miller (1996), Fomby and Carter Hill (1997), Mittelhammer, Judge and Miller (2000)) further elaborated the ME formalism originally used in the physical sciences, in order to recover information about economic systems. GME is a special case of ME where the data (i.e. consistency constraints) are represented as inexact (noisy) moments and weights are added to the entropy of the noise terms. The GME criterion proposed by Golan, Judge and Miller (1996) comprises a dual-loss function in which equal weight is usually attributed to signal (i.e. the deterministic part of the model) and noise (i.e. the entropy from the stochastic part).

The advantages and properties of the GME estimator are extensively discussed in Golan, Judge and Miller (1996), and Mittelhammer, Judge and Miller (2000). Here we only briefly list the main advantages for the problem at hand. First, the GME estimator provides estimates in cases of "negative" degrees of freedom (i.e. "ill-posed" problem). Second, the GME estimator efficiently exploits all the information contained in each data point, instead of

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[30] The milk belonging to subsistence farming is estimated as the milk from dairy farms with 1 or 2 cows.

[31] The use of productive land area instead of permanent pasture may better represent the underlying feed system of Hungary. In Hungary animal feeding is mostly based on concentrates which come from coarse grains grown on arable land EC (2002a).

using moment conditions as done by the more traditional estimators. Third, it is less influenced by outlying observations because of the weighting between signal and noise in the objective function. Fourth, it is a robust estimator, even when noise is not normally distributed and/or the design matrix ***X*** exhibits high condition indexes[32]. In addition, the GME estimator enables the researcher to easily impose prior information[33] on parameters (Golan, Perloff and Shen (2001)). These characteristics make GME particularly suited for modelling the CEECs' agriculture where data sets are limited to a few yearly/periodic data points and the underlying data-generating process is frequently unknown. The properties of the GME estimator can be derived from Golan, Judge and Miller (1996: 96-100) and Golan, Judge and Perloff (1997); those authors demonstrate that the estimator is consistent and asymptotically normal under four mild conditions[34].

In the entropy formulation as discussed in Golan, Judge and Miller (1996: 85-101), and Mittelhammer, Judge and Miller (2000: cd-rom, E. 3), the parameters are reparameterised in terms of proper probability. In order to reparameterise the parameter support space, the parameters α_{ij}, for example, need to be reparameterised in terms of a proper parameter support space and related proper probabilities. The parameter to be estimated is defined as follows: $\sum_m z_{ijm} p_{ijm} = \alpha_{ij}$, $\forall i, j$ where $\mathbf{z_{ij}} = \lfloor z_{ij1}, z_{ij2}, \ldots, z_{ijM} \rfloor'$ is an $M \times 1$ row vector of parameter supports such that $z_{ij1} < z_{ij2} < \cdots < z_{ijM}$ and M is a fixed integer with dimension $M > 2$. The parameter support space spans a uniform discrete space centred on the expected parameter value which contains the expected parameter realisation in the interval $[-a, a]$. The corresponding proper probabilities associated with the parameter support space are defined as follows, where $\mathbf{p_{ij}} = \lfloor p_{ij1}, p_{ij2}, \ldots, p_{ijM} \rfloor'$ is an $M \times 1$ row vector of unknown probabilities such that $\mathbf{p_{ij}} \in [0,1]$, and $\sum_m p_{ijm} = 1$. The parameter estimates for α_{ij} can be expressed as follows:

$$\mathbf{z_{ij}}' \mathbf{p_{ij}} = \sum_m z_{ijm} p_{ijm} = \alpha_{ij}, \qquad \text{for } i, j = 1, 2. \tag{10}$$

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[32] The GME estimator is not sensitive to multicollinearity problems (Paris (2001: 2)).

[33] Within the ME approaches the generalised cross entropy (GCE) approach also allows prior information on parameters to be incorporated directly during estimation (Golan, Judge and Miller (1996: 89-96)). The GCE criterion minimises the entropy measure between the priors and the estimated parameters. However, a GCE approach would have been unsatisfactory for introducing the more complex restrictions on parameters that were used in this paper.

[34] The mild conditions are: 1) The noise support spans a uniform and symmetric support around zero; 2) The parameter support space contains the true realisation of the unknown parameters; 3) The noises are independently and identically distributed; 4) The design matrix *X* is of full rank (Golan (2003)).

The noise terms of the supply equations (2) are also treated as unknown parameters to be estimated; for example, e_{ti} is defined as follows: $\sum_n v_{tin} w_{tin} = e_{ti} = \mathbf{v_{ti}}'\mathbf{w_{ti}}$, $\forall t, i$ where $\mathbf{v_{ti}} = [v_{ti1}, v_{ti2}, \cdots, v_{tiN}]'$ is an $N \times 1$ row vector of noise term supports (centred on zero) such that $v_{ti1} < v_{ti2} < \cdots < v_{tiN}$ and N is a fixed integer with dimension $N > 2$, $\mathbf{w_{ti}} = [w_{ti1}, w_{ti2}, \cdots, w_{tiN}]'$ is an $N \times 1$ vector of unknown probabilities such that $\mathbf{w_{ti}} \in [0,1]$, and $\sum_n w_{tin} = 1$. Similarly, the noise terms of the quasi-fixed factor equations (6 b) e_{th} are specified in a similar way as $e_{th} = \sum_n v_{thn} w_{thn} = \mathbf{v_{th}}'\mathbf{w_{th}}$, for $t = 1,\ldots, T$ and $h = 1, 2$.

In order to estimate both parameters and noise terms, the number of support points and the support bounds need to be chosen. With respect to the number of support points, Golan, Judge and Miller (1996: 138-140) show through simulation experiments that the greatest accuracy in the estimates is obtained by selecting five or more support values. Therefore the number of support points is set to five for both the parameter (M = 5) and the noise (N = 5) supports (for further details see Golan, Judge and Miller (1996: 138-140))[35].

Moving to the specification of the support bounds, two different definitions are followed for the parameter and noise components. For the parameter space definition, when the researcher does not know the possible realisations, it is suggested that $\mathbf{z}$ be set to be symmetrical around zero with large negative and positive boundaries (Golan (2003: 3)). The philosophy we have followed throughout this paper is to set the most uninformative support bounds for the parameters and then let the data, the theory and NSI determine the most likely parameter realisations. In this way, the parameter support bounds have little influence on final estimates. The parameter support bounds are arbitrarily set at plus and minus two times the maximum value of the deviation from the sample mean of the dependent variable, $[-2\tilde{\mu}, -\tilde{\mu}, 0, \tilde{\mu}, 2\tilde{\mu}]$, where $\tilde{\mu}$ is the empirical deviation from the mean of the dependent variables in the model. A similar choice was also made by Oude Lansink (1999: 108).

The noise support bounds are specified following the widely accepted 3-σ rule of Pukelsheim (1994), see also Golan, Judge and Miller (1996: 144)[36] defining a uniform zero-

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[35] Note that in principle, continuous support can also be defined.

[36] The 3-σ rule follows from the Chebychev's inequality, according to which, given a certain excluded tail probability, v^{-2}, the noise support bounds have to be proportional to the standard deviation of the underlying noises, $\pm v\sigma$. The 3-σ excludes at most one-ninth of the tail probability mass for $v = 3$ (Golan, Judge and Miller (1996: 88)).

centred distribution with a support space specified as follows: $\left[-3\tilde{\tau}, -1.5\tilde{\tau}, 0, 1.5\tilde{\tau}, 3\tilde{\tau}\right]$, where $\tilde{\tau}$ is the empirical standard deviation of the dependent variable in the model.

The reparameterised GME model leads to equations (2) and (6 b) being transformed into the following equations:

$$y_{i,t} = \sum_{m=1}^{5} z_{im} p_{im} + \sum_{j=1}^{2}\sum_{m=1}^{5} z_{ijm} p_{ijm} n_{j,t}^{n} + \sum_{h=1}^{3}\sum_{m=1}^{5} z_{ihm} p_{ihm} f_{h,t} + \sum_{n=1}^{5} v_{itn} w_{itn} \quad i = 1, 2 . \tag{11}$$

$$f_{h,t} = \frac{\sum_{m=1}^{5} z_{hm}^{\lambda} p_{hm}^{\lambda}}{\sum_{m=1}^{5} z_{hhm} p_{hhm}} \left(-\sum_{m=1}^{5} z_{hm} p_{hm} - \sum_{h \neq k}^{3}\sum_{m=1}^{5} z_{hkm} p_{hkm} f_{k,t-1} - \sum_{i=1}^{2}\sum_{m=1}^{5} z_{ihm} p_{ihm} n_{j,t-1}^{n} \right) +$$
$$\left(1 - \sum_{m=1}^{5} z_{hm}^{\lambda} p_{hm}^{\lambda}\right) f_{h,t-1} + \sum_{n=1}^{5} v_{htn} w_{htn}, \quad h = 1, 2 \text{ and } i = 1, 2 \tag{12}$$

The standard GME criterion maximises the joint entropy of all probabilities attached to the signal (**α**, **β**, **γ**, **λ**) and noise (***e***), subject to the data (the system constituted by equations (11) and (12)), and the adding-up conditions for the probabilities, symmetry, monotonicity (3 a), and convexity (3 b) conditions. Rewriting the proper probabilities in compact vector notation gives us $\mathbf{p} = \left(\mathbf{p}_i, \mathbf{p}_{ij}, \mathbf{p}_{ih}, \mathbf{p}_h^{\lambda}, \mathbf{p}_{hh}, \mathbf{p}_h, \mathbf{p}_{hk}, \mathbf{p}_{ih}\right)$ for the signal part and $\mathbf{w} = \left(\mathbf{w}_{it}, \mathbf{w}_{ht}\right)$ for the noise part. So the standard GME criterion is defined as

$$\max_{p,w} H(\mathbf{p}, \mathbf{w}) = -(1-\gamma)\mathbf{p}'\ln\mathbf{p} - \gamma(\mathbf{w}'\ln\mathbf{w}) \tag{13}$$

where $\gamma \in (0,1)$ is an exogenous parameter weighting between signal and noise. The weighted entropy criterion is used in such a way that priority is given to the within-sample prediction (achieved by setting γ equal to 0.9). The adding-up conditions for the probabilities attached to parameters and noises are:

$$\sum_{m=1}^{5} p_{im} = \sum_{m=1}^{5} p_{ijm} = \sum_{m=1}^{5} p_{ihm} = \sum_{m=1}^{5} p_{hm}^{\lambda} = \sum_{m=1}^{5} p_{hhm} = \sum_{m=1}^{5} p_{hm} = \sum_{m=1}^{5} p_{hkm} = \sum_{m=1}^{5} p_{ihm} = 1 \tag{14 a}$$

$$\sum_{n=1}^{5} w_{it} = \sum_{n=1}^{5} w_{ht} = 1 \tag{14 b}$$

The first order Lagrangian conditions yield unique and optimal values for the proper probabilities attached to parameters and noises. The point estimates for the coefficients in equations (2) and (6) are recovered from the estimated proper probabilities and the specified support points[37].

In order to assess the information content of each parameter and the effect of the introduction of NSI, we used the normalised entropy (NE) statistic (Golan, Judge and Miller (1996: 92), Golan (2003: 6)). The NE statistic for the whole system is defined by:

$$S(\tilde{\mathbf{p}}, \tilde{\mathbf{w}}) \equiv \frac{H(\tilde{\mathbf{p}}, \tilde{\mathbf{w}})}{K \log(M) + T \log(N)} \tag{15}$$

where $S \in [0,1]$. A value of one means complete uncertainty – and therefore a uniform probability distribution – whereas a value of zero indicates perfect certainty. The NE can also be computed for the parameter $S(\tilde{\mathbf{p}})$ and noise $S(\tilde{\mathbf{w}})$ parts of the model.

4.4 Estimation with non-sample information

The NSI used comprises information about elasticities derived from other economic studies and from prior information on genetic progress in milk yields. The NSI restrictions we discuss in this section are stochastic and non-linear in parameters. For our discussion, previous studies must be reviewed and exploited.

The NSI is generated following several steps. First, the expected value of the concerned parameter (or elasticity) has to be specified. If the restriction is not expressed in elasticity form, the proper measurement units should be taken into account. Second, since there will usually be a certain degree of uncertainty with respect to the NSI, the NSI restrictions will be imposed as "inexact" or stochastic equality restrictions. The underlying motivation is that imposing "inexact" restrictions may be better than ignoring all NSI and may also be preferable to assuming exact NSI. A noise term reflecting the degree of uncertainty about the prior estimates is attached to each NSI restriction. The noise is reparameterised according to GME principles, just like the other noise terms discussed above. The number of support points is set at five and the support bounds are specified in order to span a uniform deviation centred on the expected value of the NSI restriction. In this case it is not necessary to rely on the 3-σ rule of Pukelsheim (1994) since our uncertainty is assumed to be constant over time. Third, since most of the NSI constraints are also a function of the sample data, care should be taken to deal properly with the impact of variation in the data on the prior constraint

[37] To perform the estimation we used GAMS/Pathnlp. Alternatively, GAUSS, SAS or Shazam can be used. Version 9 of SAS includes a specific experimental routine to implement GME, which at the time of writing was not fully reliable. Shazam Version 10 also includes a routine for solving basic problems.

(see details below). Below, each NSI is discussed in detail. In the remainder of this section we explain how the information on elasticities from other studies is introduced. Subsequently, the information coming from well-established relations in animal husbandry is discussed. Finally, information from researcher's introspection is specified.

First, the information on behavioural responses (i.e. elasticities) is developed. As the pre-quota milk supply has been intensively analysed for the EU countries, much information is available (Oskam and Osinga (1982), Higgins (1986), Elhorst (1990), Thijssen (1992), Boots, Oude Lansink and Peerlings (1997), Colman, Solomon and Gill (2005), among others). In Table 4.1 we report the estimated elasticities of milk supplies encountered in the literature[38].

Table 4.1 Estimated and calibrated milk supply elasticities from the literature

Estimated Model	Country	Milk supply elasticity
Higgins (1986)	Ireland	0.17
Oskam and Osinga (1982)	Netherlands	0.29
Elhorst (1990)	Netherlands	0.12
Thijssen (1992)	Netherlands	0.10
Boots, Oude Lansink and Peerlings (1997)	Netherlands	0.26 - 0.43 *
Colman, Solomon and Gill (2005)	United Kingdom	0.27 - 0.36 **
Bezlepkina, Oude Lansink and Oskam (2005)	Russia	0.15
Calibrated Model	**Country**	**Milk supply elasticity**
Ledebur and Manegold (2004)	Poland/Hungary	0.30
Grethe and Weber (2005)	Poland	0.28
FAPRI (2004)	Hungary	0.11-0.20
	Poland	0.21-0.30

* Estimates have to be considered as intermediate-term elasticities. ** The data period for the estimation covers 1990–1991 and 1994–1995, during which the marketed milk was subject to a national milk marketing quota system. However, the authors argue that milk producers had no prior fixed output constraints, as they were free to buy or lease extra quotas.

The NSI estimates from this literature indicate similar estimates ranging from 0.10 to 0.43, which means an inelastic dairy supply response. Russia, which underwent a substantial reform process in the 1990s, also has an elasticity that does not differ from that of the EU countries (Bezlepkina, Oude Lansink and Oskam (2005)). Therefore there is supporting evidence that the own price elasticities of milk supply are similar across countries, which

[38] Here we consider only the studies that estimated milk supply elasticities without a supply management system.

indicates that although the dairy sectors are different, dairying operations use a similar "technology." Since in the short- and medium-runs an increase in milk yields is largely feed-driven, and given that feed technology is more limiting in the Eastern European countries than in the former EU-15 member states, it is reasonable to expect smaller elasticities than those found in Table 4.1.

A stochastic equality restriction concerning short-run milk supply elasticity is specified as:

$$\eta_{11}^{S} = \tilde{\eta}_{11}^{S} + u_{NSI_1} \tag{16}$$

where η_{11}^{S} is the own milk supply price elasticity to be estimated, $\tilde{\eta}_{11}^{S}$ is the expected value of this elasticity, and u_{NSI_1} is the uncertainty attached to the prior estimate. By substituting the own milk supply price elasticity η_{11}^{S} from equation (16) into (7) we get

$$\tilde{\eta}_{11}^{S} + u_{NSI_{1,t}} = \alpha_{11}\frac{n_{1,t}^{n}}{y_{i,t}} + e_{NSI_{1,t}} \tag{17}$$

to which an additional noise term $e_{NSI_{1,t}}$ is added, which takes into account the variation over time in the data (the ratio $n_{i,t}^{n} / y_{i,t}$). The noise term $e_{NSI_{1,t}}$ is reparameterised according to a GME formulation as follows: $\sum_{n} v_{NSI_{1,tn}}^{e} w_{NSI_{1,tn}}^{e} = e_{NSI_{1,t}}$, $\forall t$ where $\mathbf{v}_{\mathbf{NSI_{1,t}}}^{\mathbf{e}} = \left[v_{NSI_{1,t1}}^{e}, v_{NSI_{1,t2}}^{e}, \cdots, v_{NSI_{1,tN}}^{e}\right]'$ is an $N \times 1$ row vector of noise supports (centred on zero) such that $v_{NSI_{1,t1}}^{e} < v_{NSI_{1,t2}}^{e} < \cdots < v_{NSI_{1,tN}}^{e}$ and N is a fixed integer with dimension $N > 2$, $\mathbf{w}_{\mathbf{NSI_{1,t}}}^{\mathbf{e}} = \left[w_{NSI_{1,t1}}^{e}, w_{NSI_{1,t2}}^{e}, \cdots, w_{NSI_{1,tN}}^{e}\right]'$ is an $N \times 1$ vector of unknown probabilities such that $\mathbf{w}_{\mathbf{NSI_{1,t}}}^{\mathbf{e}} \in [0,1]$, $\sum_{n} w_{NSI_{1,tn}}^{e} = 1$. In this way the noise term $e_{NSI_{1,t}}$ can be estimated from $\mathbf{v}_{\mathbf{NSI_{1,t}}}^{\mathbf{e}}{}' \mathbf{w}_{\mathbf{NSI_{1,t}}}^{\mathbf{e}} = \sum_{n} v_{NSI_{1,tn}}^{e} w_{NSI_{1,tn}}^{e} = e_{NSI_{1,t}}$. The second noise u_{NSI_1} is also reparameterised in a similar way as for $e_{NSI_{1,t}}$, so that the noise term u_{NSI_1} can be estimated from $\mathbf{v}_{\mathbf{NSI_1}}^{\mathbf{u}}{}' \mathbf{w}_{\mathbf{NSI_1}}^{\mathbf{u}} = \sum_{n} v_{NSI_{1,n}}^{u} w_{NSI_{1,n}}^{u} = u_{NSI_1}$. The number of support points is set at five for both the noisy terms $e_{NSI_{1,t}}$ and u_{NSI_1} with $N = 5$. However, the specifications of the two noise support bounds differ. On one hand, the bounds for $\mathbf{v}_{\mathbf{NSI_{1,t}}}^{\mathbf{e}}$ are defined according to the 3-σ rule of Pukelsheim (1994), since in order for the restriction to hold "inexactly" at each data point, it is necessary to capture the sample scale of the ratio $n_{1,t}^{n} / y_{1,t}$. On the other hand, the bounds for $\mathbf{v}^{\mathbf{u}}_{\mathbf{NSI_1}}$ are defined in order to span a uniform deviation centred on $\tilde{\eta}^{S}_{11}$ based on the prior uncertainty of $\tilde{\eta}_{11}$[39]. For example, if it is known from the literature that $\tilde{\eta}^{S}_{11} \approx 0.25$ with extreme values equal to 0.10 and 0.40 then the support bounds are $v^{u}_{NSI_{1,1}} = -0.15$ and $v^{u}_{NSI_{1,5}} = +0.15$ respectively. Based on our literature survey, the NSI estimate in equation (17) $\tilde{\eta}^{S}_{11}$ is set at 0.10.

Less information is available on supply elasticities of the own price elasticity for beef. Some quantitative relationships for the beef supply are contained in Rayner (1975), Burton (1984), and Burrell (1992). One of the complications in using information from these studies is that they are not consistently derived from a theoretical optimisation framework as underlined by Jongeneel (2000: 175-180). However the previously cited studies complemented by Tomek and Robinson (1990), and Stout and Abler (2004) suggest that beef supply elasticities range from 0.45 to 0.80. Given that beef production is mainly a by-product of milk production for the former EU-15 Member States and the same holds for the NMS, all other things being equal, for the medium run it is expected that an increase in the price of milk would lead to an increase in the size of the national dairy herd. Since dairy cows are an important – almost sole – source of beef supply in Hungary and Poland, this would lead to an increase in beef supply (i.e. complementarity between beef and the production of milk). Following the same principle applied in equation (17) for the short-run milk supply elasticity (NSI_1), other restrictions are introduced for the medium-run milk supply elasticity (NSI_2), the medium-run beef elasticity (NSI_3), and the medium-run beef cross-price elasticity with respect to milk price (NSI_4), as stochastic restrictions. This results in adding the following restrictions as constraints during the optimisation:

$$\left(\alpha_{11} - \gamma_{11}\frac{\lambda_1}{\beta_{11}}\gamma_{11}\right)\cdot\frac{n^{n}_{1,t}}{y_{1,t}} + e_{NSI_{2,t}} = \tilde{\eta}^{M}_{11} + u_{NSI_2} \tag{18}$$

$$\left(\alpha_{22} - \gamma_{22}\frac{\lambda_2}{\beta_{22}}\gamma_{22}\right)\cdot\frac{n^{n}_{2,t}}{y_{2,t}} + e_{NSI_{3,t}} = \tilde{\eta}^{M}_{22} + u_{NSI_3} \tag{19}$$

$$\left(\alpha_{21} - \gamma_{21}\frac{\lambda_2}{\beta_{21}}\gamma_{21}\right)\cdot\frac{n^{n}_{1,t}}{y_{2,t}} + e_{NSI_{4,t}} = \tilde{\eta}^{M}_{21} + u_{NSI_4} \tag{20}$$

[39] Choosing the support bounds $v^{u}_{NSI_{1,1}}$ and $v^{u}_{NSI_{1,N}}$ is the most subjective part of specifying the stochastic equality restrictions. However this subjectivity can be reduced by selecting the most plausible and reasonable variation around the expected value $\tilde{\eta}_{11}$ after having reviewed previous studies and consulted experts.

The NSI estimates for $\tilde{\eta}_{11}^{M}$, $\tilde{\eta}_{22}^{M}$, and $\tilde{\eta}_{21}^{M}$ are set at 0.28, 0.45, and 0.14 respectively.

Second, two sources of information come from animal husbandry. The first considers the genetic trend for yield increase and the second the response of milk supply to a change in dairy cow stock. With respect to the genetic trend for yield (abbreviated NSI_5), relevant factors explaining the variation in yield increase are breed, the availability of breeding programmes (artificial insemination), and initial yield level. Moreover, the actual yield increase depends on a combination of genotype and phenotype, i.e., on genetics and environmental conditions. Information is available from dairy husbandry experts, who calculated the genetic trend in yield of US Holstein cows in 1994 to be 131 kg/cow/year (Fries and Ruvinsky (1999: 527)). Given that the US Holstein cow breeding programme is one of the world's most efficient breeding systems, it seems reasonable to consider these values as upper bounds and expect smaller values to be relevant for Hungary and Poland. Fries and Ruvinsky (1999: 527) suggest an alternative way of approximating the genetic trend: 1.3% of the average annual milk yield. Applying this, the conversion factor yields autonomous yield increase values of 70 kg/cow/year for Hungary and 50 kg/cow/year for Poland. The genetic progress restriction is specified as follows:

$$\frac{\partial y_{1,t}}{\partial f_{3,t}} = f_{1,t}\left(\frac{\partial \varsigma}{\partial f_{3,t}}\right) = f_{1,t}\tilde{r}_{13} = \gamma_{13} \qquad (21)$$

where ς represents the average milk yield. This partial derivative (which allows time to change, but keeps everything else, among which the dairy cow stock, constant) implies assuming that the change in milk production is caused solely by genetic progress. The NSI_5 is then specified as:

$$\gamma_{13}\frac{1}{f_{1,t}} = \tilde{r}_{13} \qquad (22)$$

This condition is derived from the last equality sign in equation (21), dividing both sides by $1/f_{1,t}$. Following the same principles as done for the previous restrictions (NSI_1-NSI_4), noise from two sources is added to equation (22): the first capturing the sample scale of dairy cow stock, the second representing the prior uncertainty attached to the restriction. The NSI_5 is added as constraint in the optimisation as

$$r_{13} + e_{NSI_{5,t}} = \tilde{r}_{13} + u_{NSI_5} \qquad (23)$$

where r_{13} represents the annual change in milk yields equal to $\gamma_{13}\left(1/f_{1,t}\right)$.

Next, consider the long-run response of dairy production to a change in dairy cow stock (abbreviated as NSI_6). Here it is assumed that the change in dairy production from an additional dairy cow is equal to the average milk yield it contributes, given that in the long run permanent pasture can adjust (implicitly assuming that the additional cow is not restricting the feed ration of the other dairy cows in stock). Average milk yields during the time period considered are 5200 kg/cow for Hungary and 3500 kg/cow for Poland. The (long-run) response of dairy production to a change in dairy cow stock (abbreviated as NSI_6) can be derived as:

$$\left.\frac{\partial y_{1,t}}{\partial f_{1,t}}\right|_{f_1,f_2\ variable} = \left.\frac{\partial y_{1,t}}{\partial f_{1,t}}\right|_{f_1\ variable} + \left.\frac{\partial y_{1,t}}{\partial f_{2,t}}\frac{\partial f_{2,t}}{\partial f_{1,t}}\right|_{f_1,f_2\ variable} = \gamma_{11} + \gamma_{12}\left(-\frac{\lambda_2}{\beta_{22}}\beta_{21}\right) \quad (24)$$

The NSI_6, is added as constraint in the optimisation as:

$$r_{11} = \tilde{r}_{11} + u_{NSI_6} \quad (25)$$

where r_{11} is equal to $\gamma_{11} + \gamma_{12}\left(-\frac{\lambda_2}{\beta_{22}}\beta_{21}\right)$ and $\tilde{r}_{11}$ is the prior expected value of milk yields[40]. See Table 4.2 for a summary of the NSIs used during estimation.

Table 4.2 Summary of NSI incorporated during estimation

NSI	Unit of measure	Prior estimates	Deviation
NSI_1	-	0.10	+/- 0.10
NSI_2	-	0.28	+/- 0.20
NSI_3	-	0.45	+/- 0.45
NSI_4	-	0.14	+/- 0.20
Hungary NSI_5	kg/cow/year	70	+/- 0.60
Poland NSI_5	kg/cow/year	50	+/- 0.50
Hungary NSI_6	kg/cow	5177	+/- 500
Poland NSI_6	kg/cow	3541	+/- 500
NSI	Unit of measure	Prior estimates	Deviation
NSI_1	-	0.10	+/- 0.10
NSI_2	-	0.28	+/- 0.20
NSI_3	-	0.45	+/- 0.45
NSI_4	-	0.14	+/- 0.20

Note: NSI_1 is the prior on the short-run milk supply elasticity; NSI_2 reflects the prior on the medium-run milk supply elasticity; NSI_3 represents the medium-run beef supply elasticity; NSI_4 reflects the medium-run beef cross- price elasticity with respect to milk price; NSI_5 is the prior on the genetic progress (autonomous annual yield increase); NSI_6 is the medium-run response of dairy production to a change in dairy cow stock.

Source: Authors' estimates.

[40] In equation (25) only one source of noise was added in the restriction representing the prior uncertainty attached to the restriction. This because the restriction is data-independent.

Alongside the NSIs, a set of inequality restrictions is added during the estimation. The first inequality guarantees that the supply in equation (2) is non-decreasing in quasi-fixed inputs. Assuming that the increase in production from an additional dairy cow compensates for the necessary increase in feed intake, it is expected that a unit increase in the dairy cow stock will boost milk and beef production or, at worst, leave them invariant. This implies the following inequality restrictions on parameters:

$$\gamma_{ik} \geq 0, \quad i, k = 1, 2. \tag{26}$$

The second set of inequality restrictions requires the elasticities of beef with respect to dairy cow stock to be inelastic, since beef may come from sources other than dairy cows. A similar restriction is applied for the elasticity of milk and beef with respect to permanent pasture, because hay and grass constitutes only a fraction of the total feed ration. So the condition of an inelastic beef elasticity for a change in dairy cow stocks as well as an inelastic milk and beef elasticity for a change in permanent pasture are imposed by requiring

$$\gamma_{21} \frac{f_{1,t}}{y_{2,t}} \leq 1 \tag{27 a}$$

$$\gamma_{i2} \frac{f_{2,t}}{y_{i,t}} \leq 1, \quad i = 1, 2. \tag{27 b}$$

A third set of inequality restrictions imposes the condition that the cross-price elasticities of milk and beef with respect to feed price are negative. The exploitation of the restrictions can be formulated as follows:

$$-\alpha_{ii} \frac{n_{i,t}^{n}}{y_{i,t}} - \alpha_{ij} \frac{n_{i,t}^{n}}{y_{i,t}} \leq 0, \quad i, j = 1, 2. \tag{28}$$

Finally, a set of inequality restrictions is imposed, which ensure that the stock equations are non-decreasing in the quasi-fixed inputs as well as in the milk and beef prices. This presumes that an increase in dairy cow stocks will impact positively on the investment decision related to the permanent pasture. At the same time, an increase in the prices of milk and beef is expected to generate a positive response to the investment decision for the quasi-fixed inputs. The inequality restrictions take the following form:

$$\frac{\lambda_h}{\beta_{hh}} \beta_{hk} \leq 0, \quad h = 1, 2; \quad k = 1, 2; \quad \text{with } h \neq k, \tag{29 a}$$

$$\frac{\lambda_h}{\beta_{hh}} \gamma_{ih} \leq 0, \quad h = 1, 2; \quad i = 1, 2. \tag{29 b}$$

The final GME criterion differs from the standard GME problem presented at the end of section 3 (equation (13)), in that in the maximisation it also considers all the NSI restrictions presented above, as well as all the probabilities attached to the noises accompanying these restrictions and their associated adding-up restrictions. The NSI noise part may be written as a vector of proper probabilities as $\mathbf{w}_{NSI} = \begin{pmatrix} \mathbf{w}^e_{NSI_1 t,j}, \mathbf{w}^u_{NSI_1,j}, \mathbf{w}^e_{NSI_2 t,j}, \mathbf{w}^u_{NSI_2,j}, \mathbf{w}^e_{NSI_3 t,j}, \mathbf{w}^u_{NSI_3,j}, \mathbf{w}^e_{NSI_4 t,j}, \mathbf{w}^u_{NSI_4,j}, \\ \mathbf{w}^e_{NSI_5 t,j}, \mathbf{w}^u_{NSI_5,j}, \mathbf{w}^u_{NSI_6,j} \end{pmatrix}$. The final GME criterion containing all the NSI probabilities is then equal to

$$\max_{p,w} H(\mathbf{p},\mathbf{w}) = -(1-\gamma)\mathbf{p}'\ln\mathbf{p} - \gamma(\mathbf{w}'\ln\mathbf{w} + \mathbf{w}_{NSI}'\ln\mathbf{w}_{NSI}) \tag{30}$$

where $\gamma \in (0,1)$ is again the weighting parameter. The adding-up conditions for the noise part associated with all NSI restrictions are:

$$\begin{aligned} &\sum_{j=1}^{5} w^e_{NSI1t,j} = \sum_{j=1}^{5} w^u_{NSI1,j} = \sum_{j=1}^{5} w^e_{NSI2t,j} = \sum_{j=1}^{5} w^u_{NSI2,j} = \sum_{j=1}^{5} w^e_{NSI3t,j} = \sum_{j=1}^{5} w^u_{NSI3,j} = 1 \\ &\sum_{j=1}^{5} w^e_{NSI4t,j} = \sum_{j=1}^{5} w^u_{NSI4,j} = \sum_{j=1}^{5} w^e_{NSI5t,j} = \sum_{j=1}^{5} w^u_{NSI5,j} = \sum_{j=1}^{5} w^u_{NSI6,j} = 1 \end{aligned} \tag{31}$$

The final solution to the GME problem including NSI is derived as explained in section 3.

4.5 Results

Because a detailed inspection of the data before estimation revealed some problems with multicollinearity, this section starts by presenting some diagnostic evidence on this. Thereafter the parameter estimates for the supply and stock equations are presented. Finally, the associated price and factor intensity elasticities are provided, together with some information about the model's goodness of fit.

One of our reasons for using a GME approach was the so-called ill-conditioned nature of the data. Alongside the already noted limited number of data observations, we also checked whether collinearity constituted a problem. To do so, the condition index and the variance proportions matrix as proposed by Belsley (1991) were calculated (see Tables 4.3 and 4.4)[41]. The condition index values are reported in the left-hand column in ascending order. Belsley (1991) indicates that when their values exceed 30 there is evidence for at least one linear

[41] Condition indexes are calculated as the square root of the ratios between the maximum and the minimum eigenvalues. Computations were performed using SHAZAM Version 10 (Whistler, White, Wong and Bates (2004)).

dependence. From Table 4.3 and Table 4.4, it appears that the condition indexes were generally huge across the estimated equations, particularly for Hungary. This indicates the presence of some significant multicollinearity problems in the design matrix ***X***. By looking at the row with the highest condition index, it is possible to determine the nature of collinearity by further inspecting the variance proportions matrix. Multicollinearity is present if a row associated with a high condition index contains two or more values of the variance proportions matrix that are greater than 0.5. This indicates for the supply equations there is a linear dependence between permanent pasture and the trend, both for Poland and Hungary, and for the stock equations between permanent pasture, trend and beef price for Hungary. The presence of this multicollinearity might be related to the short time length of the data, combined with the way in which the data on quasi-fixed factors were "measured." This data problem further emphasises the relevance of using a GME method (see Fraser 2000 for a study handling a similar ill-conditioned problem). The use of external sources of information (cf. the introduced NSI) is known help mitigate the effects of multicollinearity (Griffiths, Hill and Judge (1993: 369-408)).

Table 4.3 Condition index and variance proportions table (Supply Equations)

Condition index	Milk price	Beef price	Dairy cow	Perm. pasture	Trend
Hungary					
1.000	0.000	0.000	0.000	0.000	0.026
39.979	0.200	0.023	0.014	0.000	0.018
80.688	0.250	0.044	0.519	0.000	0.309
124.13	0.268	0.591	0.467	0.000	0.009
1252.2	0.282	0.342	0.000	0.999	0.638
Poland					
1.000	0.000	0.000	0.000	0.000	0.022
17.537	0.008	0.188	0.000	0.000	0.007
54.793	0.500	0.284	0.002	0.000	0.124
152.76	0.023	0.407	0.926	0.000	0.444

Source: Authors' estimates based on the condition index definition of Belsley (1991).

Table 4.4 Condition index and variance proportions table (Stock Equations)

Condition index	Dairy cow (Lagged)	Perm. pasture (Lagged)	Milk price (Lagged)	Beef price (Lagged)	Trend
			Hungary		
1.000	0.000	0.000	0.000	0.000	0.025
35.650	0.011	0.000	0.113	0.022	0.003
76.861	0.256	0.000	0.329	0.059	0.328
119.31	0.653	0.000	0.148	0.340	0.004
1575.8	0.080	0.999	0.409	0.578	0.641
			Poland		
1.000	0.000	0.000	0.000	0.000	0.025
20.226	0.000	0.000	0.035	0.192	0.002
52.796	0.001	0.000	0.652	0.469	0.104
150.22	0.899	0.000	0.011	0.326	0.570

Source: Authors' estimates based on the condition index definition of Belsley (1991).

The GME parameter estimates are provided for three different model configurations. The first (model 1) is based solely on sample data, and takes into account the homogeneity in prices and the symmetry conditions. Model 2 is similar to model 1, but also considers monotonicity (see 3 a) and convexity in prices (see 3 b). Model 3 is the model in which all the theoretical restrictions and all the NSIs are applied. To save space, the estimated parameter and error probabilities have not been included in the section; they can be requested from the authors.

No statistical tests of model parameters (like the t-values in the classical econometric approach) are provided here, for several reasons. First, the sample size (i.e. ill-posed problem) is rather small here, which undermines one of the assumptions necessary to assure the consistency and asymptotical normality of classical estimators (Golan (2003: 5)): that the noise part is independent and identically distributed for repeated samples. Fortunately, GME is able to provide robust estimates even when the underlying distribution that generated the data does not respect these conventional classical assumptions. Second, although GME performs well even under high degree of multicollinearity (Golan, Judge and Miller (1996: 133-144)), its statistical inference depends on the invertability of the cross-product matrix ***X'X***. Therefore if collinearity is present in the design matrix ***X*** it will probably increase the calculated variance of the estimated coefficients, negatively affecting the computation of the standard error and the interpretation of the *t*-tests. When discussing the results here we therefore focus on evaluating the information content of the parameter estimates using the normalised entropy for the signal and noise parts. Golan, Judge and Miller (1996: 165) suggest a value of 0.999 as a critical value for NE[42]. The normalised entropy statistics also help in assessing the three different model configurations, by determining the change in information after the different constraints have been introduced.

The parameter estimates for the dairy and beef supplies as well as for the stocks of dairy cows and permanent pasture are presented in Tables 4.5 and 4.6. The large support space specified for the reparameterised parameters implied the absence of strong prior information from the supports on the parameters. In this way it was inevitable that the final estimates would come solely from the data and the set of restrictions introduced as constraints during the estimation. Examination of the estimates of model 1 suggests that price monotonicity and convexity are violated. Poland shows a negative price response for beef, Hungary does so for cow's milk.

Table 4.5 Parameter estimates of the dairy and beef supplies for Hungary

Parameters	Hungary							
	Model 1		Model 2			Model 3		
	Estim.	$S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$
α_1	-0.2221	0.9882	-0.2247	0.9879	0.03	-0.1826	0.9921	-0.39
α_2	0.0232	0.9999	0.0216	0.9999	0.00	0.1976	0.9944	0.55
α_{11}	0.0799	0.9985	0.1324	0.9958	0.27	0.0670	0.9989	-0.05
α_{12}	0.2036	0.9901	0.0879	0.9982	-0.81	0.0123	1.0000	-0.99
α_{22}	-0.2813	0.9887	0.0583	0.9995	-1.10	0.2232	0.9929	-0.43
γ_{11}	1.1716	0.6231	1.2029	0.5985	3.95	1.0188	0.7269	-16.66
γ_{12}	-0.2945	0.9792	-0.2623	0.9836	-0.44		1.0000	-2.12
γ_{13}	0.0165	0.9999	0.0146	0.9999	0.00	0.0129	1.0000	0.00
γ_{21}	1.1573	0.7942	1.0751	0.8244	-3.81	0.6000	0.9477	-19.34
γ_{22}	0.0000	1.0000	-0.1302	0.9976	0.24	0.0534	0.9996	0.04
γ_{23}	-0.0374	0.9998	-0.0333	0.9998	0.00	-0.0408	0.9998	0.00
$\hat{\sigma}_1^2$	0.0006		0.0006			0.0010		
$\hat{\sigma}_2^2$	0.0058		0.0066			0.0089		
$S(\tilde{\mathbf{p}})$	0.9463		0.9487			0.9710		
$S(\tilde{\mathbf{w}})$	0.9950		0.9947			0.9918		
$\%\Delta S(\tilde{\mathbf{p}})$	-		-0.25			-2.61		
$\%\Delta S(\tilde{\mathbf{w}})$	-		0.04			0.32		

Note: $\hat{\sigma}^2$ is the small-sample approximated variance given by $\hat{\sigma}^2 = \frac{1}{T-1}\sum_t \hat{e}_t^2$. Changes in the normalised entropy ratios were computed using model 1 as a benchmark.

Source: Authors' estimates.

[42] For inverse problems with noise it is not uncommon to find high NE values; for an example, see Oude Lansink (1999: 110).

The signs of the coefficient attached to trend variables in the dairy and beef supplies are stable for both Hungary and Poland. Dairy shows a positive genetic trend (see γ_{13}) whereas beef shows a negative trend (see γ_{23}). This may be because there is gradual specialisation from dairy cows towards dairy production. In both Hungary and Poland, permanent pasture showed a negative impact on the dairy production for model 1 and also for model 2. This was in conflict with the monotonicity restriction for the quasi-fixed inputs in model 3 that causes the coefficient γ_{12} to be zero (see multicollinearity diagnostics). The parameters for dairy cow stock in the supply equations (see NE values for γ_{11} and γ_{21}) have the highest information content of all the parameters.

Table 4.6 Parameter estimates of the dairy and beef supplies for Poland

Parameters	Poland							
	Model 1		Model 2			Model 3		
	Estim.	$S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$
α_1	0.2517	0.9869	0.1317	0.9964	-0.97	-0.0361	0.9997	-1.30
α_2	-0.1328	0.9974	-0.1587	0.9962	0.11	0.0153	1.0000	-0.26
α_{11}	-0.0700	0.9990	0.0003	1.0000	-0.10	0.0493	0.9995	-0.05
α_{12}	-0.0315	0.9998	-0.0070	1.0000	-0.02	-0.0167	0.9999	-0.01
α_{22}	0.1511	0.9966	0.1586	0.9962	0.04	0.1791	0.9952	0.14
γ_{11}	1.1580	0.6895	1.1546	0.6915	-0.30	0.9335	0.8074	-17.10
γ_{12}	-0.3694	0.9716	-0.3452	0.9752	-0.37		1.0000	-2.92
γ_{13}	0.0246	0.9999	0.0213	0.9999	0.00	0.0114	1.0000	-0.01
γ_{21}	1.1870	0.7705	1.1808	0.7731	-0.34	0.5902	0.9469	-22.89
γ_{22}	-0.2782	0.9884	-0.2798	0.9882	0.01	0.1038	0.9984	-1.01
γ_{23}	-0.0004	1.0000	-0.0017	1.0000	0.00	-0.0195	0.9999	0.01
$\hat{\sigma}_1^2$	0.0008		0.0009			0.0011		
$\hat{\sigma}_2^2$	0.0042		0.0043			0.0063		
$S(\tilde{\mathbf{p}})$	0.9499		0.9514			0.9789		
$S(\tilde{\mathbf{w}})$	0.9921		0.9919			0.9888		
$\%\Delta S(\tilde{\mathbf{p}})$	-		-0.15			-3.05		
$\%\Delta S(\tilde{\mathbf{w}})$	-		0.02			0.34		

Note: $\hat{\sigma}^2$ is the small-sample approximated variance given by $\hat{\sigma}^2 = \frac{1}{T-1}\sum_t \hat{e}_t^2$. Changes in the normalised entropy ratios were computed using model 1 as a benchmark.

Source: Authors' estimates.

The addition of the convexity in prices in model 2, and the addition of the set of NSI restriction in model 3 resulted in an increase in the NE ratio for the parameters. One could conclude from this that the underlying data conflicted with the introduced restrictions. Alternatively, one could say that the added restrictions contributed information to the system and were welcome because they compensated for the poor signal from the data (e.g. model 1, which violates some of the most basic ideas about economic rationality in commercial dairy production).

Tables 4.7 and 4.8 provide the parameter estimates for the dairy cow and permanent pasture stocks. The stock equations complemented the supply equations by capturing medium-run dynamics in the quasi-fixed factors. For both Hungary and Poland, the stock equations exhibited relatively high normalised entropy as early as model 1.

Table 4.7 Parameter estimates of the dairy cow and permanent pasture stocks for Hungary

Parameters	Hungary							
	Model 1		Model 2			Model 3		
	Estim.	$S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$
$(\lambda_1/\beta_{11})\ \beta_1$	0.0623	0.9992	0.0930	0.9982	0.10	0.0696	0.9990	0.02
$(\lambda_1/\beta_{11})\ \beta_{12}$	-0.1273	0.9967	-0.1687	0.9941	0.25	-0.1214	0.9970	-0.03
$(\lambda_1/\beta_{11})\ \beta_{13}$	0.0038	1.0000	0.0032	1.0000	0.00	0.0060	1.0000	0.00
$(\lambda_1/\beta_{11})\ \gamma_{11}$	-0.0562	0.9994	-0.0488	0.9995	-0.02	-0.0963	0.9981	0.13
$(\lambda_1/\beta_{11})\ \gamma_{12}$	-0.0555	0.9994	-0.0436	0.9996	-0.02	-0.0567	0.9993	0.00
λ_1	0.2333	0.9888	0.2257	0.9895	-0.07	0.2588	0.9862	0.26
$(\lambda_2/\beta_{22})\ \beta_2$	-0.1502	0.9964	-0.1495	0.9982	-0.19	-0.2147	0.9925	0.38
$(\lambda_2/\beta_{22})\ \beta_{21}$	0.0493	0.9996	0.0473	0.9941	0.55		1.0000	-0.04
$(\lambda_2/\beta_{22})\ \beta_{23}$	0.0017	1.0000	0.0015	1.0000	0.00	0.0012	1.0000	0.00
$(\lambda_2/\beta_{22})\ \gamma_{21}$	0.0092	1.0000	0.0122	0.9995	0.05		1.0000	0.00
$(\lambda_2/\beta_{22})\ \gamma_{22}$	0.0000	1.0000	-0.0015	0.9996	0.04		1.0000	0.00
λ_2	0.1000	0.9984	0.1000	0.9895	0.89	0.2209	0.9921	0.63
$\hat{\sigma}_1^2$	0.0005		0.0006			0.0006		
$\hat{\sigma}_2^2$	0.0000		0.0000			0.0000		
$S(\tilde{\mathbf{p}})$	0.9981		0.9979			0.9970		
$S(\tilde{\mathbf{w}})$	0.9986		0.9986			0.9980		
$\%\Delta S(\tilde{\mathbf{p}})$			0.02			0.11		
$\%\Delta S(\tilde{\mathbf{w}})$			0.00			0.06		

Note: $\hat{\sigma}^2$ is the small-sample approximated variance given by $\hat{\sigma}^2 = \frac{1}{T-1}\sum_t \hat{e}_t^2$. Changes in the normalised entropy ratios were computed using model 1 as a benchmark. The partial adjustment coefficient λ_h which is defined as $0 < \lambda_h < 1$, was restricted to lie between 0.1 and 0.9 since the GAMS optimisation procedure does not allow the exclusion of bounds. However, this did not affect the partial adjustment estimates for model 3, where the constraints are actually not binding.

Source: Authors' estimates.

Table 4.8 Parameter estimates of the dairy cow and permanent pasture stocks for Poland

Parameters	Poland							
	Model 1		Model 2			Model 3		
	Estim.	$S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$	Estim.	$S(\tilde{\mathbf{p}}_k)$	$\%\Delta S(\tilde{\mathbf{p}}_k)$
$(\lambda_1/\beta_{11})\ \beta_1$	-0.1161	0.9969	-0.1165	0.9969	0.00	0.0938	0.9980	-0.11
$(\lambda_1/\beta_{11})\ \beta_{12}$	0.1753	0.9930	0.1758	0.9930	0.00		1.0000	-0.70
$(\lambda_1/\beta_{11})\ \beta_{13}$	0.0022	1.0000	0.0022	1.0000	0.00	0.0066	1.0000	0.00
$(\lambda_1/\beta_{11})\ \gamma_{11}$	-0.0508	0.9994	-0.0509	0.9994	0.00	-0.1133	0.9971	0.23
$(\lambda_1/\beta_{11})\ \gamma_{12}$	-0.0521	0.9994	-0.0521	0.9994	0.00	-0.0717	0.9988	0.06
λ_1	0.1000	0.9977	0.1000	0.9977	0.00	0.1497	0.9949	0.28
$(\lambda_2/\beta_{22})\ \beta_2$	-0.4660	0.9252	-0.4664	0.9251	0.01	-0.4948	0.9153	1.06
$(\lambda_2/\beta_{22})\ \beta_{21}$	0.1023	0.9965	0.1024	0.9965	0.00		1.0000	-0.35
$(\lambda_2/\beta_{22})\ \beta_{23}$	0.0041	1.0000	0.0041	1.0000	0.00	0.0003	1.0000	0.00
$(\lambda_2/\beta_{22})\ \gamma_{21}$	-0.0304	0.9997	-0.0303	0.9997	0.00	-0.0250	0.9998	-0.01
$(\lambda_2/\beta_{22})\ \gamma_{22}$	0.0071	1.0000	0.0072	1.0000	0.00	-0.0044	1.0000	0.00
λ_2	0.3883	0.9485	0.3885	0.9484	0.00	0.5279	0.9032	4.77
$\hat{\sigma}_1^2$	0.0007		0.0007			0.0006		
$\hat{\sigma}_2^2$	0.0000		0.0000			0.0000		
$S(\tilde{\mathbf{p}})$	0.9880		0.9880			0.9839		
$S(\tilde{\mathbf{w}})$	0.9788		0.9788			0.9759		
$\%\Delta S(\tilde{\mathbf{p}})$			0.00			0.41		
$\%\Delta S(\tilde{\mathbf{w}})$			0.00			0.30		

Note: $\hat{\sigma}^2$ is the small-sample approximated variance given by $\hat{\sigma}^2 = \frac{1}{T-1}\sum_t \hat{e}_t^2$. Changes in the normalised entropy ratios were computed using model 1 as a benchmark. The partial adjustment coefficient λ_h which is defined as $0 < \lambda_h < 1$, was restricted to lie between 0.1 and 0.9 since the GAMS optimisation procedure does not allow the exclusion of bounds. However, this did not affect the partial adjustment estimates for model 3, where the constraints are actually not binding.

Source: Authors' estimates.

The normalised entropy for the system increased, particularly in model 3, both for the signal and noise parts. The partial adjustment coefficient λ_h ranges from 0.26 to 0.10 for Hungary and from 0.53 to 0.10 for Poland. This means that for Hungary and for Poland (except for model 3) the demand for the quasi-fixed factors mainly depends on the lagged levels achieved.

Table 4.9 and Table 4.10 report the associated own-price elasticities for the short and medium runs, as well as the elasticities of intensity. If we had not relied on external sources of information, the sample data would often have provided spurious results that would run counter to what we know about dairying (see results from model 1). All own-price elasticities are less than one, implying inelastic dairy and beef supply responses. The medium-run animal feed price elasticities from model 3 vary from -0.12 to -0.48 for Poland and from -0.06 to -

0.48 for Hungary. The sign of the cross-price elasticity for Hungary indicates complementarity between milk and beef production in the short run. In both countries, the effect of the dairy cow stock adjustment, as captured in the medium-run own-price elasticities, is greater for milk than for beef.

Table 4.9 Price elasticities and elasticities of intensity at the sample mean for Hungary

	Price elasticity						Elasticity of intensity	
	Short Run			Medium Run				
Model 1	milk	beef	feed	milk	beef	feed	cow	land
milk	0.1269	*0.2362*	-0.3631	0.2495	*0.3116*	-0.5611	1.1512	-0.3737
beef	*0.3948*	-0.3982	0.0034	*0.5209*	-0.2930	-0.2279	1.3877	0.0000
Model 2	milk	beef	feed	milk	beef	feed	cow	land
milk	0.2105	*0.1019*	-0.3124	0.3227	*0.1628*	-0.4855	1.1819	-0.3329
beef	*0.1704*	0.0825	-0.2529	*0.2722*	0.1539	-0.4261	1.2892	-0.2015
Model 3	milk	beef	feed	milk	beef	feed	cow	land
milk	0.1064	*0.0143*	-0.1207	0.2653	*0.0813*	-0.3467	1.0011	0.0000
beef	*0.0239*	0.3160	-0.3399	*0.1360*	0.3449	-0.4809	0.7195	0.0827

Note: From the price homogeneity condition we recovered the cross-price elasticities with respect to animal feed price by simply adding up the own-price elasticities and cross-price elasticities.

Source: Authors' estimates.

Table 4.10 Price elasticities and elasticities of intensity at the sample mean for Poland

	Price elasticity						Elasticity of intensity	
	Short Run			Medium Run				
Model 1	milk	beef	feed	milk	beef	feed	cow	land
milk	-0.1205	*-0.0413*	0.1618	-0.0032	*0.0377*	-0.0345	1.0943	-0.4682
beef	*-0.0731*	0.2670	-0.1939	*0.0669*	0.3966	-0.4635	1.5129	-0.4756
Model 2	milk	beef	feed	milk	beef	feed	cow	land
milk	0.0005	*-0.0092*	0.0086	0.1174	*0.0696*	-0.1870	1.0912	-0.4375
beef	*-0.0162*	0.2804	-0.2642	*0.1234*	0.4087	-0.5321	1.5052	-0.4783
Model 3	milk	beef	feed	milk	beef	feed	cow	land
milk	0.0848	*-0.0219*	-0.0629	0.2549	*0.0657*	-0.3206	0.8822	0.0000
beef	*-0.0388*	0.3165	-0.2777	*0.1165*	0.3606	-0.4771	0.7523	0.1774

Note: From the price homogeneity condition we recovered the cross-price elasticities with respect to animal feed price by simply adding up the own-price elasticities and cross-price elasticities.

Source: Authors' estimates.

In order to check the model performance, the first order correlation coefficients between observed and predicted values were computed for the estimated supplies and stock adjustment equations (see Table 4.11). With the exception of the permanent pasture stock equation for Poland, the correlations are all higher than 0.90, indicating that for both countries the estimated models have a good within-sample predictive performance. The addition of convexity in prices in model 2, and the NSI restrictions in model 3 in general lead to only a slight decrease in the within-sample predictive power of the model as compared to model 1 (the exception being the dairy cow stock equation of Poland in model 3).

Table 4.11 Correlation between observed and predicted values

Hungary	Milk	Beef	Dairy cow	Permanent pasture
Model 1	0.9692	0.9551	0.9797	0.9975
Model 2	0.9706	0.9482	0.9796	0.9975
Model 3	0.9571	0.9295	0.9781	0.9900
Poland	Milk	Beef	Dairy cow	Permanent pasture
Model 1	0.9371	0.9387	0.9789	0.6291
Model 2	0.9344	0.9375	0.9789	0.6292
Model 3	0.9143	0.9047	0.9814	0.5634

Source: Authors' estimates.

4.6 Discussion and conclusions

In this paper we have developed an econometrically estimated dairy and beef supply model for Hungary and Poland, which includes the adjustment dynamics in quasi-fixed factors (dairy cow stock and land). The model was estimated by applying a mixed GME estimator, which allows for the inclusion of SI and NSI and as such could cope with the severe data problems that were faced. To our knowledge this is the first attempt to provide empirical estimates of dynamic dairy and beef models for these new EU member states. The estimated model satisfied theoretical consistency as well as plausibility (i.e. the results were largely in accordance with previous economic studies and animal husbandry information about dairy farming). Traditional estimation techniques based solely on sample data would have been unable to provide "workable results" of any help for policy analysis. According to our results, dairy and beef show inelastic own price responses in Hungary and Poland. Our estimated supply elasticities of milk production appear to be of the same order of magnitude as the calibrated elasticities used for partial equilibrium models, which take into account dairy for Hungary and Poland. More precisely, our estimated supply elasticities of milk production are on average about 85 percent of the calibrated elasticities used in the GAPsi model (Ledebur, E. O. v. and D. Manegold (2004)) and are on average about 106 of the upper range of the calibrated elasticities used in the FAPRI model (FAPRI (2004)) models. In this way it is empirically proven that without loss of generality the calibrated elasticities used in the literature are not far from reality. In addition, we found complementarity between the production of milk and beef in the medium run. Our finally estimated model showed satisfactory within-sample predictive power, which makes it suitable for policy analyses.

Appendix 4.1

Descriptive statistics

Table A4.1 Descriptive Statistics

	Hungary		Poland	
	Mean	S.D.	Mean	S.D.
Milk	0.7577	0.0930	0.7912	0.0811
Beef	0.6208	0.2558	0.5866	0.1858
Dairy cow	0.7445	0.1169	0.7478	0.1261
Permanent pasture	0.9613	0.0225	1.0028	0.0085
Milk price	1.2040	0.1719	1.3624	0.2247
Beef price	0.8789	0.0639	1.0369	0.2187

Source: Authors' calculations.

CHAPTER 5
Dairy farm size distribution in Hungary and Poland

Abstract

In recent decades, both Western agriculture and post-socialist countries have undergone significant structural changes. During the 1990s, Central and Eastern European Countries (CEECs) experienced even more dramatic adjustments connected to the transition reform from a socialist regime to a market-oriented economy. The aim of this paper is to empirically analyse the evolution of the dairy farm structure of Hungary and Poland during the post-socialist period. A generalized cross entropy (GCE) Markov chain approach which incorporates prior information is applied. Prior information included general and plausible information on farm mobility and structural adjustments. The projections show that dairy farm numbers will continue to decline, although accompanied by an increase in the number of medium-sized and large farms. In the coming six years, the decline in total number of dairy farms is expected to be about 55 per cent in Hungary and 36 per cent Poland. Subsistence dairy farms are expected to slowly leave the sector in the coming decade – more slowly in Poland than in Hungary.

Tonini, A., R. Jongeneel. Dairy farm size distribution in Hungary and Poland. Submitted for publication in *Applied Economics*.

5.1 Introduction

In recent decades, both Western agriculture and post-socialist countries have undergone significant structural changes. Common patterns are a decline in the contribution of agriculture to GDP, a decline in the number of farms, contraction in rural employment, and gains in productivity and efficiency. The structure of dairy farming is also changing. Dairy production is being scaled-up, reducing the number of dairy farms and increasing the herd size per farm. The upscaling is being mirrored by an intensification of production, increasing the environmental pressure of the sector. A common trend in European Union (EU) countries is the increase in the number of dairy holdings and animals in large herd classes, with a concomitant decline in the number of small farms. In the EU, the decline in the number of dairy cows and the number of holdings led to the number of cows per holding rising (to an average of 33 cows per farm) over the period 1990-2001 (OECD (2004: 58)).

During the 1990s, Central and Eastern European Countries (CEECs) experienced even more dramatic adjustments connected to the transition reform from a socialist regime to a market oriented economy. Some of the most important changes after transition were particularly to do with the agrarian structures. The reform required the establishment of well-defined legal property rights and the attribution/restitution of agricultural assets to private owners (Swinnen, J. F. M. and E. Mathijs (1997: 335-345)). One of the aims of the reform was to foster viable farms out of the mostly inefficient state and collective structures (Tonini, A. and R. Jongeneel (2006)). By the mid-1990s, land privatization had largely been achieved in all Eastern European countries, creating greater diversity in terms of legal status, size and ownership structures. In 1994, one third of the land area of Hungary was equally distributed among state farms, cooperatives, and individual farms, whereas in 1996 about 88 per cent of the land area in Poland was already privately owned (Mathijs, E. and S. Meszaros (1997: 172), EC (1998a: 50).

Both Hungary and Poland are important dairy producers within the EU-25: in 2005 they respectively accounted for about 1.4 and 8.7 per cent of the total EU-25 cow milk production, being the first and third milk producers respectively among the new member states. In the last five years, dairy cow numbers in Hungary and Poland have declined by 13.0 and 9.4 per cent respectively and milk yields have improved by 7.3 and 15.1 per cent (FAO (2006)). The accession to the EU required the gradual compliance with the *acquis communautaire*, which required significant improvements in the milk quality standards. The adoption of the new EU regulations which were partly anticipated by the downstream sector through the stream of Western foreign direct investments (FDI) forced small and inefficient farms to leave the sector or merge in large-scale organizations, thereby affecting the post-socialist dairy farm structure (Gow, H. R. and J. Swinnen (1998)).

The aim of this paper is to empirically analyse the evolution of the dairy farm structure of Hungary and Poland during the post-socialist period. Attention is given to how the farm structure has changed over time and to what path it is likely to follow in the coming decade. Moreover, farm mobility and the question of which farms are likely to survive in the future are addressed. Finally, it is tested whether the evolution of farm size is dependent on economic, policy and environment variables and the impact and directions of these dependencies are clarified.

The paper's contribution can be characterized in a number of ways. First, an innovative estimation procedure is applied, which enables us to cope with the data limitations and exploit sources of prior information about farm structure and mobility. Second, the paper contributes to the scanty literature analysing the dairy farm size evolution of Hungary and Poland in the post-socialist period (Tonini, A. and R. Jongeneel (2002), Jongeneel, R., N. Longworth and S. Huettel (2005)).

This study extends the approaches used in Tonini, A. and R. Jongeneel (2002) and Jongeneel, R., N. Longworth and S. Huettel (2005) in several ways. Compared to Tonini, A. and R. Jongeneel (2002) this study considers noisy moment consistency constraints relying on an enriched estimation technique. Compared to Jongeneel, R., N. Longworth and S. Huettel (2005) the estimation procedure used in this paper directly accommodate for a seemingly unrelated regressions approach and in addition the stationary assumption is tested relying on more disaggregated farm size classes.

The analysis contained in this paper is interesting and helpful for the different stakeholders in the sector. It addresses the interest of policy makers in providing insight into how the farm structure will evolve in the new member states of the EU. Relevant issues are whether the farm structure of the CEECs will be able to accelerate its restructuring and converge to an EU farming style, and what will happen to the subsistence farms in the restructuring process. Last but not least, the analysis is of interest also for the upstream and downstream industries that have to decide on investments in dairy processing capacity, milk collection schemes, and providing farm input supplies in these countries.

The remainder of this paper is organized as follows. Section 5.2 describes the farm structure of Hungary and Poland, with a focus on dairy farming. Section 5.3 specifies the

Markov entropy formalism. Section 5.4 describes the data used and discusses results. In section 5.5 the conclusions are presented.

5.2 Farm structure in Hungary and Poland, with a focus on dairy farming

This section discusses the main characteristic of the agrarian farm structure in Hungary and Poland, emphasizing similarities and differences. The second part of the section throws light on their dairy farm structure, on which the empirical analysis will focus.

The socialist farm structure differed greatly from the farm structure of Western market economies. In the socialist countries, land was largely state-owned, with few exceptions (notably Poland). Production decisions were centralized, and large corporate farms were frequently favoured by state plans and socialist policies (Lerman, Z. (2005: 3)). The farm structure in many CEECs was dual in a sense that there was a symbiosis between large corporate state farms and household plots. For a more comprehensive analysis on farm structure in the CEECs see Swinnen, J. F. M. and E. Mathijs (1997). Farm structure has been analysed in Hungary by Juhasz, J. (1991) in particular, and in Poland by Csaki, C. and Z. Lerman (2002) among others.

During the socialist regime, the collectivization process was stronger in Hungary than in Poland. In the 1950s and early 1960s in Hungary, under the Comecon system peasant farmers were obliged to put their land and other agricultural assets in the cooperatives. By contrast, in Poland about 80 per cent of the land was already privately owned before reform (EC (2002b: 8)). In both Hungary and Poland, there were three main farm organizations: state farms, cooperative farms, and household plots (Swinnen, J. F. M. and E. Mathijs (1997)). State farms were very large farms with hired workers. In Hungary in 1989 there were 136 state farms with an average size of 6,886 hectares and accounting for about 4 per cent of the land farmed by collective farms (Mathijs, E. and S. Meszaros (1997: 162)). In Poland, the state farms were approximately 500 hectares on average, although they covered 20 per cent of the total land in 1989 (EC (1998a: 52)). Cooperative farms comprised members who owned several agricultural assets and/or offered labour; they were usually smaller than the state farms. They were the most widespread structure in Hungary, accounting for about 50 per cent of total agricultural output (Keane, M. and P. Byrne (1992a: 5)) whereas in Poland they accounted only about 4 per cent of the total agricultural area (Keane, M. and P. Byrne (1992b: 15)). Both state farms and cooperatives were important organizations for providing services such as repair shops and grain storage to small private farms. Household plots in Hungary were very small farms intensively cultivated by members of collective farms or state farm workers, whereas in Poland they were entirely owned by private family farms. In the early 1990s in Hungary, 1.4 million people were cultivating household plots, representing 15 per cent of the arable land (Keane, M. and P. Byrne (1992a: 5)). In Poland, small farms are a balanced mix of crops, livestock and cheap family labour and only about 20 per cent of small farmers obtain income exclusively from farming[43].

Because there were so many state farms and cooperatives in Hungary, land privatization proceeded more slowly than in Poland. However, as a result of land privatization and asset restitution, the variety of farm organizations in terms of legal status and ownership structure increased more in Hungary than in Poland. For a description of the emerging post-socialist farm structures in Hungary, see (Mathijs and Meszaros, 1997).

The literature (Juhasz, J. (1991: 412-415), Mathijs, E. and S. Meszaros (1997: 168-175)) suggests a depolarization in the post-socialist period in Hungary: from very small and very large organizations to medium-sized business organizations. In contrast, in Poland there is a tendency for polarization, with small farms persisting together with recently increasing numbers of medium–large farms (Csaki, C. and Z. Lerman (2002), Sznajder, M. (2002)). On one hand, the more dynamic farms grow through land purchase and by investing in modern equipment. On the other hand, medium-sized farms are either expanding by purchasing and leasing new assets, or surviving by exploiting off-farm income sources and reselling or leasing out land (Czyzewski, A. B., W. M. Orlowski, L. Zienkowski, Z. Zolkiewski and W. Guba (2000: 171)). In Hungary, the emerging group of corporations represented by business associations, such as limited liability and joint stock companies, was fuelled by the dismantling of the former state farms (which disappeared from 1996) and old cooperatives (which also declined after transition). The post-socialist cooperatives, whose members were concomitantly joint owners of the organizations, gradually declined after transitions. Hungary and Poland were both characterized by the presence of very small household plots producing for the family (i.e. subsistence farming). In Hungary, the share of private owners on land grew rapidly post-transition, to the disadvantage of the other organizations inherited from the past regime. Private holdings in Hungary were cultivating about 60 per cent of the total agricultural area in 2000 (EC (2002a: 8)), compared with more than 90 per cent of the area in

[43] According to the Agricultural Census of 2002, the total number of individual holdings larger than 1 hectare of agricultural land included 17 per cent operating on a non-permanent or temporary basis, 10.6 per cent subsistence farms, 25.5 per cent semi-subsistence farms, and 46.8 per cent commercial farms, see Zmija, J. and E. Tyran (2004: 74).

Poland (EC (2002b: 8)). However, in Poland about 58 per cent of private farms owned less than 5 hectares in 2004, representing about 20 per cent of the total agricultural land, which suggests there was much land fragmentation (PCSO (2005)).

So far, the focus has been on the agricultural sector as a whole. However, what holds for agriculture in general is also reflected in the evolution of the dairy sector. The Hungarian dairy sector during the socialist regime was characterized by a dual farm structure with large agricultural enterprises on one side and very small holdings on the other (Szábo (2000: 34-35)). In 1989, just at the time of transition, there were 82 dairy state farms and 292 dairy cooperatives, having respectively an average herd size of about 1293 cows and 292 cows; whereas the remaining 80 000 small farms had on average 1.7 cows (IDF (1992: 33)). Farms were typically mixed enterprises rather than specialized in dairying. Almost 60 per cent of cows were kept in cooperatives, with the remainder being equally distributed between state farm and household plots (Keane and Byrne (1992A: 8)). The primary dairy production tended to be concentrated in large-scale organizations. For a long time, cooperatives and state farms produced about 80 per cent of the total Hungarian milk production, while the remaining 20 per cent was produced by small-scale farms (OECD (1994: 111)). A more recent study (Carlier (2000: 13)), shows that about 75 per cent of the total dairy production in one of Hungary's main dairy regions (i.e. Zala region) came from producers with over 300 cows, who represented less than 2 per cent of the total producers.

The post-socialist dairy farm structure in Hungary is a dual structure with large organizations (enterprises and cooperatives) on the one hand and smallholdings on the other. For example, in 2005, 67 per cent of the cows were kept in large-scale organizations with an average herd size larger than 200 cows (see Table 5.1). This underlines that Hungary has largely preserved the former socialist farm size structure, although it has undergone a massive privatization process during its restructuring, which mostly affected legal status and property ownership.

The total aggregate number of holdings keeping cows has been declining continually (see also Table 5.2), accompanied by an increase in the average number of cows per holding. The decline in the number of dairy farms is largely attributed to the contraction of the classes of small dairy farms (1-2 cows, 3-9 cows). The numbers of farms with 10-19 cows and with more than 100 cows have also been declining, although more slowly than the remaining farm-size categories.

Table 5.1 Dairy farm structure in Hungary, 1995-2005

Year	Cattle				Cow			
	Enterprises	Cooperatives	Small holdings	Total	Enterprises	Cooperatives	Small holdings	Total
	In thousands of heads of cattle/cow							
1995	265	406	257	928	118	178	125	421
1996	272	391	246	909	121	169	124	414
1997	242	349	280	871	109	155	139	403
1998	251	328	294	873	116	150	141	407
1999	288	268	302	857	132	122	145	399
2000	543		262	805	261		119	380
2001	497		238	804	238		130	368
2002	494		276	770	240		122	362
2003	489		250	739	233		117	350
2004	475		249	723	225		121	345
2005	474		234	708	225		109	334
	Number of holdings							
1995	323	658	62000	62981	287	629	49000	49916
1996	322	603	55000	55925	287	603	43000	43890
1997	274	561	48000	48835	256	542	39000	39798
1998	271	508	43000	43779	252	489	36000	36741
1999	317	439	40000	40756	299	421	32000	32720
2000				52180[1)]				35190[1)]
2003				32250[1)]				22000[1)]
	Average herd size							
1995	820	617	4.1		411	283	2.6	
1996	845	648	4.4		422	280	2.9	
1997	883	622	5.8		426	286	3.6	
1998	926	646	6.8		458	289	3.9	
1999	908	610	7.6		441	290	4.5	

Source: Kiss and Weingarten (2002), HCSO (2005) [1)] Eurostat (2006a).

Table 5.2 Holdings in Hungary in 2000 and 2003, by number of dairy cows

Class	1-2	3-9	10-19	20-29	30-49	50-99	> 100	Total
2000	21850	11040	1130	270	170	140	610	35190
2003	13050	6840	980	280	190	170	490	22000
Growth	-40.27	-38.04	-13.27	3.70	11.72	21.43	-19.67	-37.48
				Relative shares in %				
2000	62.09	31.37	3.21	0.77	0.48	0.40	1.73	100.00
2003	59.32	31.09	4.45	1.27	0.86	0.77	2.23	100.00

Source: Eurostat (2006a).

On one hand this suggests that large former collective dairy farms were also going out of business and downsizing to small units. There was still a class of medium-sized dairy farms that was growing over time and supporting the depolarization pattern previously described for the agricultural sector.

Since the socialist regime, the Polish dairy sector has presented a highly fragmented dairy farm structure, with a large number of small private family farms, just as in other sectors of agriculture. At the beginning of transition, about 80 per cent of the national milk production was produced from farms with 10 cows or less. This structure is very different to the situation encountered in Hungary, where milk production has tended to be dominated by large cooperatives. In 1987, about 67 per cent of the dairy farms had only 1-2 cows and these accounted for 41 per cent of the national herd (see Table 5.3). As Table 5.3 also shows, the number of private dairy farms had already shrunk greatly before transition (by about 25 per cent in a period of six years). In fact, this pattern of decline in the pre-transition period shows up for all size classes. Dairy cow numbers declined concomitantly.

In Poland, dairy producers after transition can be classified in three main categories: farmers with 1-2 cows, who produce milk mostly for the farm household (i.e. subsistence dairy farms); farmers with more than 3-4cows, who produce milk for sale in local markets and for their own needs (i.e. semi-subsistence dairy farms); and farmers with more than 10 cows, who produce almost exclusively for the dairy industry (Sznajder (2002: 248)). The on-farm consumption and direct sales were often more attractive than processing, especially for the small dairy farms (farms with 1-2 cows) which were unable to make the necessary adjustments in their production facilities. In 1996, about one quarter of Polish milk was produced by almost 1 million of individual farms holding 1 to 3 cows, while half was produced by farms with 3 to 9 cows (EC (1998a: 36)). This underscores the great fragmentation in production.

Table 5.3 Dairy farm structure in Poland, 1981 and 1987 (thousands)

Class	1-2	3-5	6-10	> 11	Total
1981	1275.0	578.4	108.8	10.6	1972.8
1987	978.9	406.8	76.0	6.7	1468.4
Growth	-23.2	-29.7	-30.1	-36.8	-25.6
			Structure in %		
1981	64.6	29.3	5.5	0.5	100.0
1987	66.7	27.7	5.2	0.5	100.0
			Dairy Cow Stock		
1981	1917.8	2076.5	767.5	142.8	4904.6
1987	1769.5	1773.8	648.5	103.1	4295.0
Growth	-7.7	-14.6	-15.5	-27.8	-12.4
			Structure in %		
1981	39.1	42.3	15.6	2.9	100.0
1987	41.2	41.3	15.1	2.4	100.0

Source: Sznajder (2002: 244).

In 2005 there were about 700 000 dairy farms: a decline of about 51 per cent compared with the number of farms in 1995 (see Table 5.4). In the same year, about 65 per cent of the farms with dairy cows belonged to subsistence farms with 1-2 cows and about 53 per cent of the dairy cow stock was concentrated in farms with 1-9 cows. The Polish Ministry of Agriculture forecast a 76 per cent decline in the number of total farms from 1996 to 2010 (AgraEurope (2000: 18-19)).

Table 5.4 Holdings with dairy cows in Poland (thousands), by number of dairy cows

Class	1	2	3-9	10-29	30-49	50-99	100-199	> 200	Total
1995	588.741	426.224	404.978	10.961	0.164	0.207	0.134	0.038	1431.447
1996	547.122	363.004	376.293	20.256	0.246	0.218	0.141	0.040	1307.320
1997	602.537	382.105	399.105	20.402	0.288	0.214	0.139	0.039	1404.946
1998	521.565	346.342	384.686	33.572	0.448	0.195	0.113	0.032	1286.953
1999	500.702	305.151	324.887	37.400	0.638	0.191	0.122	0.029	1169.120
2000	487.552	268.103	293.167	40.840	0.842	0.230	0.108	0.023	1090.865
2001	460.108	254.944	263.854	46.301	1.126	0.205	0.086	0.032	1026.656
2002	401.522	192.017	225.601	52.468	2.250	0.490	0.161	0.071	874.580
2003	352.409	184.040	212.749	57.284	3.190	0.608	0.136	0.049	810.465
2004	334.000	152.443	183.546	61.120	3.657	0.874	0.127	0.041	735.808
2005	316.469	141.659	170.341	65.959	4.646	1.098	0.139	0.044	700.355
Growth	-46.25	-66.76	-57.94	501.76	2732.93	431.65	4.06	16.11	-51.07
Structure in %									
1995	41.13	29.78	28.29	0.77	0.01	0.01	0.01	0.00	100.00
1996	41.85	27.77	28.78	1.55	0.02	0.02	0.01	0.00	100.00
1997	42.89	27.20	28.42	1.45	0.02	0.02	0.01	0.00	100.00
1998	40.53	26.91	29.89	2.61	0.03	0.02	0.01	0.00	100.00
1999	42.83	26.10	27.79	3.20	0.05	0.02	0.01	0.00	100.00
2000	44.69	24.58	26.87	3.74	0.08	0.02	0.01	0.00	100.00
2001	44.82	24.83	25.70	4.51	0.11	0.02	0.01	0.00	100.00
2002	45.91	21.96	25.80	6.00	0.26	0.06	0.02	0.01	100.00
2003	43.48	22.71	26.25	7.07	0.39	0.08	0.02	0.01	100.00
2004	45.39	20.72	24.94	8.31	0.50	0.12	0.02	0.01	100.00
2005	45.19	20.23	24.32	9.42	0.66	0.16	0.02	0.01	100.00
Dairy cow stock in %									
1996	17.1	22.7	50.6	7.9	0.3	0.5	0.6	0.4	100.0
1998	15.4	20.5	49.8	12.7	0.5	0.4	0.4	0.3	100.0
1999	16.2	19.7	46.2	16.0	0.7	0.4	0.5	0.3	100.0
2000	16.5	18.1	44.5	18.7	1.0	0.5	0.5	0.2	100.0
2001	16.1	17.8	41.5	22.1	1.4	0.5	0.4	0.3	100.0
2002	14.6	14.0	38.3	27.4	2.9	1.2	0.8	0.8	100.0
2003	12.8	13.4	36.4	30.8	4.0	1.4	0.7	0.6	100.0
2004	12.6	11.5	32.7	35.2	4.9	2.0	0.6	0.5	100.0
2005	12.0	10.7	30.0	37.5	6.2	2.5	0.7	0.5	100.0

Source: Krawiecka (2005).

5.3 The model

5.3.1 The basic GCE Markov model

The Markov chain technique has a long history in agricultural economics (Judge and Swanson (1962), Lee, Judge and Zellner (1970)). The approach assumes that any given population (e.g. firms, individuals) can be classified into different states. Movements from state to state are represented by a stochastic process and are typically modelled by estimating the so-called Markov transition probabilities. The Markov chain approach is very suitable when the only data available are count data in the form of observable proportions or aggregates which reflect the behaviour of micro units. The Markov chain technique is able to cast the problem in a form in which probabilities may be used to represent our partial information on the individual dynamic micro behaviour that may have produced the macro outcomes.

It is often the case that the proportions/count data are only available for a limited number of years, so that the number of unknowns in terms of transition probabilities to be estimated exceeds the number of data points. In this context, the maximum entropy (ME) algorithm developed in Golan, Judge and Miller (1996), Fomby and Carter Hill (1997), and Mittelhammer, Judge and Miller (2000) is a suitable candidate for extracting the maximal signal from an initial "out-of-focus" problem. The maximum entropy formalism for the Markov problem is developed in Lee and Judge (1996) and Golan, Judge and Miller (1996).

For the greatest generality, the Generalized Cross Entropy (GCE) formulation is presented, from which the Generalized Maximum Entropy (GME) can be derived as a special case (Golan, Judge and Miller (1996: 89-93)). The GCE formalism is based on the directed divergence or minimal discriminability principles of Kullback (1959) and Good (1963). In words, this approach minimizes the distance between the probabilities that are consistent with the data and the prior information incorporated during estimation. It therefore has a strong connection with the Bayes information processing rules, since both techniques transform prior and sample information into posterior information (Lee and Judge (1996: 160-162)).

GCE is suitable when some "educated" guesstimates based on previous data, experiments or economic theory are available[44]. It is important to note that the GCE

[44] Prior information for the problem at hand included general and plausible information on farm mobility and structural adjustments.

formalism differs greatly from the case of restricted estimators where constraints must always hold[45]. The GCE can be thought of as a more general degenerated GME method in which priors are allowed to deviate from the uniform distribution. GCE selects out of all feasible solutions the one that minimizes the distance between the data and the priors, the final solution being the closest to the priors. So, the prior signal can be overruled by the signal coming from the sample data.

In formalizing the problem, the GCE Markov problem can be stated as follows:

$$\min I(p_{lk}, q_{lk}, w_{tkh}, u_{tkh}) = \sum_l \sum_k p_{lk} \ln(p_{lk} / q_{lk}) + \sum_t \sum_k \sum_h w_{tkh} \ln(w_{tkh} / u_{tkh}) \qquad (1)$$

subject to the following constraints:

$$y_{tk} = \sum_l x_{tl} p_{lk} + e_{tk} \qquad (2)$$

with

$$e_{tk} = \sum\nolimits_h V_{tkh} w_{tkh} \qquad (3)$$

and

$$\sum_k p_{lk} = 1 \qquad (4)$$

$$\sum_h w_{tkh} = 1 \qquad (5)$$

Equation (1) represents the GCE function which minimizes the distance between the data in the form of posterior Markov transition probabilities p_{lk} and the Markov transition priors q_{lk}. By analogy, the GCE algorithm minimizes also the distance between the error in the form of posterior probabilities w_{tkh} and the priors u_{tkh}; p_{lk} are the elements of a $L \times K$ squared matrix of transition probabilities where *l, k* =1,...,*K* and q_{lk} are the counterpart prior elements; w_{tkh} are the elements of a $TKH \times 1$ vector of error posterior probabilities and u_{tkh} are the counterpart prior elements.

Equation (2) represents the Markov data consistency constraints or moment condition, where y_{tk} are the elements of a $TK \times 1$ vector of known proportions falling in the *k*-th Markov states in time (t+1), x_{tl} are the elements of a $TL \times 1$ vector of known proportions falling in the *l*-th Markov states in time (t). In order to obtain the proportions falling in each *k*-th Markov state as required typically for a Markov formulation, the aggregate round counts

[45] For an example where stochastic restrictions on parameters are included, see Tonini and Jongeneel (2005).

y_{tk} and x_{tl} are usually normalized by a common scalar. The Markov transition probabilities p_{lk} directly enter in the GCE objective function (1) without needing to be reparameterized.

In order to make our problem more realistic, an error term e_{tk} is included in equation (2) in order that the data consistency constraint in equation (2) may not hold exactly. Each element e_{tk} is reparameterized as given by equation (3) following the Shannon's entropy formulation, where $\mathbf{V}_{tk}$ is an H-dimensional vector of support points and $\mathbf{w}_{tk}$ is an H-dimensional vector of proper probabilities with $H \geq 2$. In defining the $\mathbf{V}_{tk}$ vector, Golan and Vogel (2000: 459) suggest setting the support vector with $\mathbf{V}_{tk} = \left[-1/K\sqrt{T},\ldots,0,\ldots,1/K\sqrt{T}\right]$. This definition of error support is based on the fact that $e_{tk} \in [-1;1]$ since the elements y_{tk} and x_{tl} are expressed in terms of proportions. Equation (4) represents the set of additivity constraints for the required Markov row constraint, while Equation (5) does so for the proper probabilities of the reparameterized error. All proper probabilities of signal and noise are required to be non-negative $(\mathbf{p},\mathbf{w}) >> 0$. The optimization of the problem (1) – (5) following Golan, Judge and Miller (1996: 89-93) yields the following solutions:

$$\tilde{p}_{lk} = \frac{q_{lk}\exp\left(\tilde{\lambda}_k x_l\right)}{\sum_k q_{lk}\exp\left(\tilde{\lambda}_k x_l\right)} = \frac{q_{lk}\exp\left(\tilde{\lambda}_k x_l\right)}{\Omega_l\left(\tilde{\lambda}\right)} \tag{6 a}$$

and

$$\tilde{w}_{tkh} = \frac{u_{tkh}\exp\left(\tilde{\lambda}_k V_{tkh}\right)}{\sum_h u_{tkh}\exp\left(\tilde{\lambda}_k V_{tkh}\right)} = \frac{u_{tkh}\exp\left(\tilde{\lambda}_k V_{tkh}\right)}{\Psi_k\left(\tilde{\lambda}\right)} \tag{6 b}$$

where u_{tkh} are taken to be uniform with $u_{tkh} = 1/H$ when no prior information is available on the error term. A common procedure is to normalize (6.a) and (6.b) by $\lambda_1 = 0$, since *T* of the *TK* Lagrange multipliers are redundant[46] (Golan, Judge and Miller (1996: 52)).

The estimation procedure allowed for the possibility of non-zero covariances following the one-step GCE Seemingly Unrelated Regressions (SUR) described by Golan, Judge and Miller (1996: 186). A similar approach was also followed in Gillespie and Fulton (2001) although for a multinomial Logit formulation. In contrast to the two-stage estimation procedure usually applied in conventional estimation procedures, the unknown elements of the error covariance matrix are now jointly estimated with the unknown Markov transition

[46] From the primal solutions in (6.a) and (6.b) the dual unconstrained problem can be derived in the same way.

probabilities. The one-step GCE-SUR requires the following additional consistency constraints to be added during the estimation:

$$\frac{1}{T}\sum_{t=1}^{T} e_{tk}e_{tg} = \delta_{kg}\left[\left(\frac{1}{T}\sum_{t=1}^{T} e_{tk}e_{tk}\right)\left(\frac{1}{T}\sum_{t=1}^{T} e_{tg}e_{tg}\right)\right]^{1/2}, \text{ for } k \neq g \qquad (7)$$

where $\delta_{kg}^2 = \sigma_{kg}^2 / \sigma_{kk}\sigma_{gg}$. The unknown covariance correlation coefficient δ_{kg} [47] is simultaneously estimated without the need to be reparameterized with the rest of the unknowns for each pair $k \neq g$, and $k, g = 1, 2, \ldots, K$.

When uniformly distributed priors (uninformative priors) are assumed, the GME estimates are equivalent to the GCE solutions. The relative information content of the estimated parameters can be evaluated through the normalized entropy measure for the signal and noise parts of the problem (Golan, Judge and Miller (1996: 93)). Being a relative entropy statistic, the normalized entropy measure can also be used for model comparisons. The signal normalized entropy for the GCE problem is defined as

$$S(\tilde{\mathbf{p}}) = \frac{-\tilde{p}_{lk}\ln(\tilde{p}_{lk})}{-q_{lk}\ln(q_{lk})} \qquad (8\text{ a})$$

By analogy, the noise-normalized entropy is defined as

$$S(\tilde{\mathbf{w}}) = \frac{-\tilde{w}_{tkh}\ln(\tilde{w}_{tkh})}{-u_{tkh}\ln(u_{tkh})} \qquad (8\text{ b})$$

where $S(\cdot)$ measures the concentration or probability mass over the bounded support space[48]. The measure is defined for values between zero and one, with values approaching zero in the case of perfect information (i.e. perfectly degenerated distribution) and values approaching one in the case of perfect uncertainty (i.e. uniform distribution). An equivalent measure is the information index $I(\cdot)$ where $I(\cdot) = 1 - S(\cdot)$ (Soofi (1992)).

In the entropy formalism, a statistical analogue to the likelihood ratio statistic is the so-called Entropy-Ratio (ER) which follows a $\chi^2_{(K-1)}$ distribution (Golan and Vogel (2000: 445-454), Golan, Perloff and Shen (2001: Appendix)). For example, denote ℓ' as the maximum unconstrained objective function value (problem including the data) and ℓ'' as the maximum constrained objective function value where no data consistency constraints are

[47] A more general formulation of the one-step GCE-SUR would have been to allow the unknown covariance correlation coefficient to vary over time too.

[48] In the case of a GME approach, the normalization factor in the denominator of (8.a) and (8.b) has to be substituted by the constrained entropy value when no data consistency constraints are enforced.

included. Then for the GCE case, ℓ'' is simply given by $-\mathbf{q}\ln(\mathbf{q})-\mathbf{u}\ln(\mathbf{u})$. Thus the ER statistic for the noisy GCE case is

$$ER_{GCE}=2[\ln\ell''-\ln\ell']=2[\mathbf{q}\ln(\mathbf{q})+\mathbf{u}\ln(\mathbf{u})]\cdot\left[1-\frac{\tilde{\mathbf{p}}\ln(\tilde{\mathbf{p}})}{\mathbf{q}\ln(\mathbf{q})}+\frac{\tilde{\mathbf{w}}\ln(\tilde{\mathbf{w}})}{\mathbf{u}\ln(\mathbf{u})}\right] \tag{9}$$

An additional entropy statistic can be defined to test whether the rate of shrinkage associated with the priors is statistically significant (Golan and Vogel (2000: 455)). This statistic follows a χ^2 distribution with (K – 1) degrees of freedom. Consider $\{p_{ij}\}$ as the set of K observed frequency distributions where each distribution is over K observations, then let the null hypothesis be $H_0: \mathbf{p}=\mathbf{q}$, then the statistic is defined as $\chi^2_{(K-1)}\sim\sum_i\sum_j\frac{1}{q_{ij}}(p_{ij}-q_{ij})^2$. The smaller the priors, the higher the weights of the χ^2 statistic will be. Since the objective in a GCE approach is to minimize the distance between the data and the initial prior beliefs, high values for the χ^2 statistic implies that the prior beliefs are rejected by the data.

5.3.2 The instrumental variable GCE Markov non-stationary problem

Due to the structure of the classical Markov problem, only the aggregate count data at year (t) and (t+1) are subject to the data consistency constraint given in equation (2). So in the most conventional applications, a purely stochastic Markov process is considered, where the matrix describing the transition probabilities between different states is assumed to be constant over time (i.e. stationary Markov models) (see Krenz (1964), Keane (1991), among others). However, considering the dynamic farm growth process, it is possible to envisage that farm growth can be explained through the effects of several variables. Several economic variables are in fact expected to affect the unknown transition probabilities[49]. When the researcher has this knowledge it is possible to incorporate this information under the more general instrumental variable formulation as developed in Golan and Vogel (2000) and Courchane, Golan and Nickerson (2000), therefore increasing the power of the model to explain non-stationary effects on the single Markov transition probabilities. In addition, as the proposed approach is based on an instrumental variable-like approach, it allows the circumvention of potential measurement issues in the data that may affect data from post-

[49] For example, a literature review suggests that out of all possible covariates the following appear to be likely to affect the transition probabilities of dairy farms: technological shift, milk price, feed price, dairy cow stock price (see Goddard, Weersink, Chen and Turvey (1993), Zepeda (1995b), and Karantininis (2002).

socialist countries (Griffiths, Hill and Judge (1993: 460-462)). One limitation of the IV-GCE approach is that the type of covariate cannot differ across the different Markov states. Other approaches have explicitly modelled non-stationary Markov transition probabilities; for an overview of these models see Zepeda (1995a, 1995b) and Gillespie and Fulton (2001).

Starting from the moment condition in equation (2) and incorporating the covariates z_{tn}, forming a $T \times N$ matrix, produces a newly specified data consistency constraint as given by:

$$\sum_t z_{tn} y_{tk} = \sum_t \sum_l z_{tn} x_{tl} p_{lk} + \sum_t z_{tn} e_{tk}, \quad \forall n = 1,\ldots,N, \text{ and } \forall k = 1,\ldots,K \tag{10}$$

The assumption underlying equation (10) is that the covariates are correlated with the aggregate Markov farm size categories y_{tk} and x_{tl}. Still, no specific functional relationships are assumed between the covariates z_{tn} and the x_{tl} variables.

In the IV-GCE problem, the GCE objective function in (1) remains unchanged and the minimization of (1) subject to (2) - (5) yields the following new IV-GCE solutions (see Appendix 5.2 which has been developed following Golan, Judge and Miller (1996: 89-93) and Golan and Vogel (2000: 458-459):

$$\tilde{p}_{lk} = \frac{q_{lk} \exp\left[\sum_t \sum_n \tilde{\lambda}_{nk} z_{tn} x_{tl}\right]}{\sum_k q_{lk} \exp\left[\sum_t \sum_n \tilde{\lambda}_{nk} z_{tn} x_{tl}\right]} = \frac{q_{lk} \exp\left[\sum_t \sum_n \tilde{\lambda}_{nk} z_{tn} x_{tl}\right]}{\Omega_l\left(\tilde{\lambda}_n\right)} \tag{11}$$

and

$$\tilde{w}_{tkh} = \frac{u_{tkh} \exp\left[\sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh}\right]}{\sum_h u_{tkh} \exp\left[\sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh}\right]} = \frac{u_{tkh} \exp\left[\sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh}\right]}{\Psi_k\left(\tilde{\lambda}_n\right)} \tag{12}$$

Several "probability" elasticities can be computed (see Appendix 5.3 for details). One type of elasticity considers the effect of x_{tl}, the vector of proportion falling in the *l*-th Markov state in time (t), on the transition probabilities p_{lk} as given by:

$$\eta_{lk}^{x} = \frac{\partial \tilde{p}_{lk}}{\partial x_{tl}} \frac{\bar{x}_l}{\tilde{p}_{lk}} = \bar{x}_l \left[\sum_n \tilde{\lambda}_{nk} \bar{z}_n - \sum_k \tilde{p}_{lk} \sum_n \tilde{\lambda}_{nk} \bar{z}_n\right] \tag{13}$$

Another set of elasticities captures the effects of the covariates z_{tn} on the transition probabilities p_{lk}, as given by:

$$\eta_{lkn}^{p} = \frac{\partial \tilde{p}_{lk}}{\partial z_{tn}} \frac{\bar{z}_n}{\tilde{p}_{lk}} = \bar{x}_l \bar{z}_n \left[\tilde{\lambda}_{nk} - \sum_k \tilde{p}_{lk} \tilde{\lambda}_{nk} \right] \tag{14}$$

Finally, it is also possible to determine the cumulative effects of a unit change in each covariate z_{tn} on y_{tk}, the vector of proportion falling in the *k*-th Markov state in time (t+1), as given by:

$$\eta_{kn}^{y} = \frac{\partial y_{kt}}{\partial z_{tn}} \frac{\bar{z}_{tn}}{\bar{y}_k} = \frac{\bar{z}_n}{\bar{y}_k} \sum_l \left[\tilde{p}_{lk} \bar{x}_l^2 \left(\tilde{\lambda}_{nk} - \sum_k \tilde{p}_{lk} \tilde{\lambda}_{nk} \right) \right] \tag{15}$$

5.3.3 The GCE prior information treatment

Using aggregate size class data alone it is not possible to determine which individual farms are exiting and entering the sector and whether the farms in a given *k*-th Markov states at time (t+1) are the same farms that were in the *l*-th Markov states at time (t) or are farms that have shifted from other size categories. So, relying on a Markov chain approach it is only possible to focus on net changes between different farm size classes. As indicated earlier, the Markov problem can be undetermined in the sense that the number of unknowns to be estimated may be larger than the number of available data points for estimation. It is therefore helpful to use some sort of prior information in order to recast the Markov problem in a more tractable and realistic way. In a GCE approach, prior information on the unknowns to be estimated can be directly introduced during the estimation procedure.

In order to clarify what kind of prior information can be used, an example is elaborated partly based on Bostwick (1962). Consider a Markov chain in which the unit under scrutiny is a frog in a lily pond. The frog in its status quo is sitting on one of the finite lily pads in the pond and can jump to other lily pads. Although the frog can randomly decide its strategy to move back and forward, it can only afford certain pads because the length of its jumps is physically limited, as is the number of jumps which it can afford to make within a certain period of time. In addition, the degree of randomness of the frog is controlled by its intelligence. For example, an intelligent frog would rather jump to other lily pads rather than land in the water. Therefore by following the previous example, the researcher may try to control the frog's movements by guessing two kind of information: one is related to the frog's capacity to make jumps (length and number), the other is related to the degree of randomness attached to each jump.

In our case, the physical energy of the frog can be associated to the underlying dynamic farm size growth process. In this way, farms cannot jump to farm size classes (lily pads) that are too far away from their initial status, because they have several structural and financial constraints (physical energy limitations). In addition, the researcher may guess or estimate the probability of a farm ending up in a Markov state. For example, if the frog is sufficiently intelligent, one would expect that after many jumps it will not end up in its initial position but instead will stay on its final pad because it has expended much energy to achieve its pad and needs to recover. By analogy, it may be expected that any given farm in the largest farm size category exploiting scale economies will persist in that size class rather than moving back to very small farm size classes. Given this, the researcher may follow several principles in order to best approximate the farm size growth and to guess or estimate the probability to be in a given size class. For example, a common practice is to restrict most of the lower and upper off-diagonal elements of the transition probability matrix to zero, increasing the number of degrees of freedom (Disney, Duffy and Hardy Jr (1988), Zepeda (1995b)).

Concerning the farm growth process, here some of the main assumptions underlying the choice of the priors are outlined and country-specific characteristics are then discussed in defining the priors for each country. The following general assumptions have been made in setting our problem:

1. Most of the dairy farms tend to persist in the same size class over time, whereas net movements from one size to another usually interests only a small fraction of the total number of farms in a given size class;
2. Dairy farmers of any herd size will expand their herd size whenever possible. This is usually a widely accepted opinion on farm growth and is concomitantly consistent with the presence of scale economies in dairy farming[50]. There is evidence that scale economies have forced many small dairy producers either to merge with larger operations or to go out of business (Lyson and Gillespie (1995: 494));
3. The dairy farms most likely to expand are those with a larger than average herd. By pursuing scale economies, large dairy farms usually have lower production costs per unit produced than small dairy farms. It is expected that large farms are in a better financial position to scale up by purchasing land and increasing their herd size;

[50] Poland has been cited as one of the most competitive countries in the EU based on the cost of milk production. The most competitive Polish dairy farms are in the north-west of the country and have on average 50 dairy cows and an average cost equal to 14 US-$/100 Kg of milk. However, dairy farms with more than 50 cows only constitute about 0.19 per cent of the total number of dairy farms in Poland (IFCN (2004)).

4. Increases in dairy farms are most likely to be gradual. This is particularly true for post-socialist economies which have had problems in optimally adjusting their size to the presence of frictions in clearing land markets due to undetermined property rights, liquidity constraints and lack of capital (Swinnen and Mathijs (1997), Tonini and Jongeneel (2002));
5. Decreases in farm size are possible, although they are less likely than increases in farm size. As discussed under points (1) and (2), due to scale economies, farmers are more likely to expand rather than to shrink their herd. This contrasts with Krenz (1964), who did not allow downsizing in farm size;
6. Dairy farms which are not productive for a given year may exit from the sector. This is most likely to occur for dairy farms with a smaller than average herd size. Small private farms which are unable to upgrade their facilities are likely to leave the sector because they are unable to comply with market regulations. The exit from the sector also depends on the development of off-farm labour opportunities in the country.

The exit and re-entering of dairy farms is often captured within a Markov chain framework by an artificial absorbing category which is added to the initial Markov states. So the final *k*-th Markov transition states are denoted by a subscript *l, k* defined for $l, k = 0,1,\dots,K$, where the index associated with zero refers to the exit and re-entry size class.

In order to determine the magnitude of each single prior transition probability the first step was to approximate the calculated the per annum continuous growth rate for each size class. However this computation was considered only as a rough guideline in order to get an estimate for the number of farms remaining in the same size class over time. It is a rough estimate because it does not directly account for in- and out-flow from the Markov state. It should be emphasized that within a GCE approach, prior information does not necessarily need to be exact in nature, since this information is balanced with the data stochastically.

For Hungary, the possibility of re-entry was not allowed ($p_{00} = 1$,) since only two count data were available and the total number of dairy farms over the period analysed only declined. In addition, exits were specified only for those farms with less than 9 cows, and for the largest farm size class with more than 100 cows, since numbers of these farms were declining over time. In order to save degrees of freedom, farms were allowed only to scale-down or scale-up by one size category. In defining the magnitude of the priors, the Markov states were assumed to persist in the same state, with probabilities ranging from 0.59 for the small farm size classes (1-2 cows) to 0.85 for the remaining farm sizes. In addition, exit and scaling-down were dominant for the farms with less than 9 cows, whereas farms with more than 10 cows could scale-up at higher rate than the rest of the farms. This was supported by the fact that small farms are frequently hamstrung because of shortage of capital and availability of credible collaterals. The prior matrix used for Hungary is presented in the Appendix in Table A5.1.

For Poland, farm re-entry was allowed, since the aggregate number of dairy farms did not continually decline over the sample under scrutiny (see Table 5.4 in section 5.2). Re-entry was allowed only for the dairy farms with more than 10 cows. This seems a reasonable assumption, given that dairy farms with less than 10 cows are producing for their own consumption and/or local markets and are not expected to increase in the short term but rather go out of business when economic conditions improve (Sznajder (2002)). In addition, exit was specified only for those farms with less than 9 cows, in a similar way as done for Hungary. Given the expected growth for the small–medium farm size classes, farms with 3-49 cows were allowed to scale-up by more than one farm size class. In defining the magnitude of the priors, the Markov states were assumed/estimated to have a probability ranging from 0.80 to 0.99 of persisting in the same state. The probabilities of scaling-down and scaling-up were equally balanced, with expectations fixed at 0.05 — with the exception of the large size farm categories, where scaling-up was dominant over scaling-down. The prior matrix used for Poland is presented in the Appendix in Table A5.2.

5.4 Data and estimation results

This study used aggregate data on the size distribution of dairy farms. Holdings were classified according to their herd size classes. The data for Hungary cover the years 2000 and 2003 and allow the recovery of the number of dairy farms belonging to seven farm size classes: 1-2 cows, 3-9 cows, 10-19 cows, 20-29 cows, 30-49 cows, 50-99cows, > 100 cows (Eurostat (2006a)). The data for Poland cover the period from 1995 to 2005 and allow the recovery of the number dairy farms belonging to eight farm size classes: 1 cow, 2 cows, 3-9 cows, 10-29 cows, 30-49 cows, 50-99 cows, 100-199 cows, > 200 cows (Krawiecka (2005))[51]. Data were normalized by a common scalar equal to the maximum number of farms contained in the aggregate transition counts[52].

[51] In this analysis for Poland, we intentionally kept the categories for farms with 1 cow and farms with 2 cows disaggregated, since our focus was partly on the evolution in dairy farm size of small subsistence farming

For Poland, in order to capture non-stationary effects coming from the surrounding economic environment several policy variables potentially affecting the transition probability were considered, as well as non-policy variables approximating the environment of the dairy sector. Among the potentially available covariates, several selection criteria were followed. First, the policy relevance of the variables in influencing farm growth was examined, also referring to previous studies. Second, the degree of collinearity among the covariates and between the covariates and the transition count data was analysed. In this way it was possible to select the covariates which were largely correlated with the transition counts, in order to increase the efficiency of the IV-GCE estimates. Three covariates were selected: a trend variable capturing technical change in the dairy environment z_{t1}, a deflated index of cow milk producer price z_{t2}, and a deflated index for concentrates for cattle excluding calves z_{t3}. The last two covariates are thought to be policy variables influencing the transition probabilities. These variables were from Eurostat (2006b).

The stationary GCE approach including the priors on single transition probabilities as described in section 5.4.2 (stationary Markov chain model) was initially estimated for Hungary and Poland. The normalized signal entropy $S(\tilde{\mathbf{p}})$ for the system was 1.0000 for Hungary and 0.9518 for Poland. The information index $I(\tilde{\mathbf{p}})$ or pseudo-R^2 was 0.00 for Hungary and 0.0482 for Poland. The χ^2 statistic was 0.0003 for Hungary and 0.0306 for Poland, indicating that the estimated transition probabilities did not statistically differ from the priors at five per cent significance level with K=22 and K=36 degrees of freedom. In addition, the ER statistic was 0.00 and 0.2301 respectively for Hungary and Poland, indicating that the contribution of the *KT* data consistency constraints was not statistically significant. A similar result had earlier been obtained by Golan and Vogel (2000: 465).

The relatively high scores for the normalized signal entropy underline that the data did not push the final estimates away from the prior. There are several possible reasons for this finding. First, the number of data points available for the estimation was insufficient to significantly influence the parameter estimates – particularly for Hungary, which had a severe lack of degrees of freedom. Hungary had only one transition for eight farm size classes including inactive farms: a total of eight data points.

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potentially characterized by differences in dynamic behaviour. In addition, for Poland the problem was not ill-posed, in the sense that there were insufficient degrees of freedom to allow for this disaggregation.

[52] Another possibility could have been to normalize the aggregate round count data by the total number of farms in a given year.

Table 5.5 Estimated transition probability matrix using a stationary GCE for Hungary

Classes*	0	1-2	3-9	10-19	20-29	30-49	50-99	> 100	$S(\tilde{\mathbf{p}}_i)$
0	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000
1-2	0.40754	0.58240	0.01006	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000
3-9	0.35161	0.04943	0.58903	0.00993	0.00000	0.00000	0.00000	0.00000	0.99901
10-19	0.08009	0.00000	0.05002	0.84988	0.02001	0.00000	0.00000	0.00000	1.00000
20-29	0.00000	0.00000	0.00000	0.05000	0.85000	0.10000	0.00000	0.00000	0.99997
30-49	0.00000	0.00000	0.00000	0.00000	0.03000	0.85000	0.12000	0.00000	1.00000
50-99	0.00000	0.00000	0.00000	0.00000	0.00000	0.03000	0.85000	0.12000	0.99999
> 100	0.12006	0.00000	0.00000	0.00000	0.00000	0.00000	0.03000	0.84994	1.00000

Source: Author's estimates. * No. of cows.

Table 5.6 Estimated transition probability matrix using a stationary GCE for Poland

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200	$S(\tilde{\mathbf{p}}_i)$
0	0.99272	0.00000	0.00000	0.00000	0.00562	0.00087	0.00069	0.00009	0.00001	0.96508
1	0.09927	0.86206	0.03867	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.78816
2	0.08875	0.06126	0.79681	0.05319	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000
3-9	0.04226	0.00000	0.04768	0.85503	0.04555	0.00621	0.00288	0.00039	0.00000	0.93126
10-29	0.00000	0.00000	0.00000	0.05024	0.89968	0.04995	0.00010	0.00003	0.00000	1.00000
30-49	0.00000	0.00000	0.00000	0.00000	0.05000	0.90000	0.04990	0.00011	0.00000	1.00000
50-99	0.00000	0.00000	0.00000	0.00000	0.00000	0.02000	0.93000	0.05000	0.00000	1.00000
100-199	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01000	0.95000	0.04000	1.00000
> 200	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.99999	1.00000

Source: Author's estimates. * No. of cows.

However, the estimated Markov transition probability matrix consisted of 24 Markov transition probabilities to be estimated, which results in a lack of 16 degrees of freedom. In this context, when the problem is ill-posed or undetermined, it is not unexpected for the prior to have a strong impact on the final estimates. For Poland, the stationary Markov problem was not undetermined, given that 90 data points are available to estimate 37 Markov transition probabilities. This also explains why the normalized signal entropy of the stationary Markov model estimated for Poland was lower than that estimated for Hungary. Tables 5.5 and 5.6 present the estimated stationary GCE Markov transition probability matrixes for Hungary and Poland respectively.

The estimated transition probability matrix itself already provides insight into the dynamic adjustment of dairy farms. For example, for both countries during the period considered there is a strong tendency for farms to persist in the same size class from one year to the next (see transition probabilities on the diagonals). The off-diagonal elements of the transition matrix provide information on the extent dairy farms are going to scale up or down. For example, for Poland, about 4 per cent of all farms with only 1 cow will probably grow into a dairy farm with 2 cows.

The IV-GCE approach was also estimated for Poland. In this way, from the most significant variables for dairy production three covariates were selected, introducing a trend for structural change, a deflated index of cow milk producer price, and a deflated index for concentrates for cattle excluding calves[53]. The signal normalized entropy $S(\tilde{\mathbf{p}})$ for the system was 0.9487 and the information index $I(\tilde{\mathbf{p}})$ 0.0513. The χ^2 statistic was 0.0321, indicating that our prior beliefs were accepted by the data as found for the stationary model. The ER statistic was 0.1672 for the model including all three covariates, 0.0744 for the model including only the trend, 0.1267 for the model including only the cow milk price, and only 0.1301 for the model only including the price of concentrates. Although the calculated value for the ER statistic is significantly below the critical value at five per cent significance level, the calculated ER statistics favour the model including all three covariates.

[53] In a preliminary version of the model, two additional variables were also considered, such as a deflated price index for cattle and gross domestic product at constant prices. However, their introduction notably increased the degree of multicollinearity among the introduced covariates. The cattle price index was strongly correlated with the deflated price index for milk, whereas the GDP correlated strongly with the trend variable.

Table 5.7 Estimated transition probability matrix using an IV-GCE for Poland

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200	$S(\tilde{\mathbf{p}}_i)$
0	0.99319	0.00000	0.00000	0.00000	0.00527	0.00081	0.00064	0.00008	0.00001	0.91252
1	0.09804	0.86326	0.03870	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.78396
2	0.08744	0.06114	0.79809	0.05333	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000
3-9	0.04187	0.00000	0.04752	0.85578	0.04540	0.00618	0.00287	0.00039	0.00000	0.92771
10-29	0.00000	0.00000	0.00000	0.05023	0.89971	0.04994	0.00010	0.00003	0.00000	1.00000
30-49	0.00000	0.00000	0.00000	0.00000	0.05000	0.90000	0.04990	0.00011	0.00000	1.00000
50-99	0.00000	0.00000	0.00000	0.00000	0.00000	0.02000	0.93000	0.05000	0.00000	1.00000
100-199	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01000	0.95000	0.04000	1.00000
> 200	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.99999	1.00000

Source: Author’s estimates. * No. of cows.

Table 5.8 Dairy farm size x_l elasticity for the Markov transition probabilities p_{lk}

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200
0	-0.00002900	0.02734900	0.00584000	0.01234500	0.00334500	0.00584900	0.00801500	0.00880000	0.00893200
1	-0.03604000	0.00531100	-0.02717700	-0.01735000	-0.03094400	-0.02716300	-0.02389100	-0.02270600	-0.02250600
2	-0.00635200	0.01843000	-0.00104000	0.00484900	-0.00329800	-0.00103200	0.00092900	0.00163900	0.00175900
3-9	-0.01071200	0.01574700	-0.00504100	0.00124700	-0.00745200	-0.00503200	-0.00293900	-0.00218000	-0.00205200
10-29	-0.00047400	0.00280800	0.00023000	0.00100900	-0.00006900	0.00023100	0.00049000	0.00058500	0.00060000
30-49	-0.00002400	0.00008700	0.00000003	0.00002600	-0.00001000	0.00000007	0.00049000	0.00058500	0.00060000
50-99	-0.00000900	0.00002100	-0.00000200	0.00000500	-0.00000500	-0.00000200	0.00000900	0.00001200	0.00001300
100-199	-0.00000400	0.00000700	-0.00000100	0.00000100	-0.00000200	-0.00000100	-0.00000031	0.00000000	0.00000005
> 200	-0.00000100	0.00000200	-0.00000038	0.00000042	-0.00000069	-0.00000038	-0.00000011	-0.00000002	0.00000000

* No. of cows.

Source: Author's estimates.

Table 5.9 Trend z_1 elasticity for the Markov transition probabilities p_{lk}

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200
0	0.00029700	-0.06353700	-0.06358600	-0.06167100	-0.04233800	-0.04670500	-0.04617400	-0.04629800	-0.04629600
1	0.08696300	-0.00945000	-0.00952400	-0.00663100	0.02256800	0.01597300	0.01677500	0.01658800	0.01659000
2	0.05267300	-0.00510700	-0.00515100	-0.00341700	0.01408200	0.01012900	0.01061000	0.01049800	0.01049900
3-9	0.05648200	-0.00521000	-0.00525700	-0.00340600	0.01527800	0.01105800	0.01157100	0.01145100	0.01145300
10-29	0.00525300	-0.00239800	-0.00240400	-0.00217400	0.00014300	-0.00038100	-0.00031700	-0.00033200	-0.00033200
30-49	0.00018900	-0.00006900	-0.00006900	-0.00006200	0.00001700	-0.00000099	0.00000100	0.00000066	0.00000066
50-99	0.00005000	-0.00001900	-0.00001900	-0.00001700	0.00000400	-0.00000056	0.00000002	-0.00000012	-0.00000011
100-199	0.00001900	-0.00000700	-0.00000700	-0.00000600	0.00000200	-0.00000016	0.00000005	0.00000000	0.00000000
> 200	0.00000600	-0.00000200	-0.00000200	-0.00000200	0.00000049	-0.00000005	0.00000002	0.00000000	0.00000000

* No. of cows.

Source: Author's estimation.

Table 5.10 Cow's milk price z_2 elasticity for the Markov transition probabilities p_{lk}

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200
0	-0.00072500	0.15336300	0.17835500	0.11757700	0.10455600	0.10857700	0.10970500	0.11048600	0.11058600
1	-0.21137300	0.02135700	0.05910500	-0.03269300	-0.05235900	-0.04628700	-0.04458200	-0.04340300	-0.04325300
2	-0.14360500	-0.00413100	0.01849100	-0.03652400	-0.04830900	-0.04467000	-0.04364900	-0.04294200	-0.04285200
3-9	-0.11168700	0.03723000	0.06138400	0.00264500	-0.00993900	-0.00605300	-0.00496200	-0.00420800	-0.00411200
10-29	-0.01272100	0.00574700	0.00874300	0.00145800	-0.00010300	0.00037900	0.00051500	0.00060800	0.00062000
30-49	-0.00044200	0.00018200	0.00028300	0.00003700	-0.00001600	0.00000058	0.00000500	0.00000800	0.00000900
50-99	-0.00011900	0.00004700	0.00007400	0.00000800	-0.00000600	-0.00000100	-0.00000002	0.00000083	0.00000093
100-199	-0.00004400	0.00001700	0.00002700	0.00000300	-0.00000200	-0.00000076	-0.00000031	0.00000000	0.00000004
> 200	-0.00001400	0.00000500	0.00000800	0.00000087	-0.00000075	-0.00000025	-0.00000011	-0.00000001	0.00000000

* No. of cows.

Source: Author's estimates.

Table 5.11 Compound feed price for cattle excluding calves z_3 elasticity for the transition probabilities p_{lk}

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200
0	0.00039900	-0.06247600	-0.10892900	-0.04356100	-0.05887300	-0.05602300	-0.05551700	-0.05538800	-0.05535700
1	0.08837000	-0.00659600	-0.07675700	0.02197400	-0.00115300	0.00315100	0.00391600	0.00411000	0.00415700
2	0.08458000	0.02766800	-0.01437900	0.04479000	0.03093000	0.03350900	0.03396800	0.03408400	0.03411200
3-9	0.04449200	-0.01627400	-0.06116800	0.00200700	-0.01279100	-0.01003700	-0.00954700	-0.00942400	-0.00939300
10-29	0.00699500	-0.00054100	-0.00610900	0.00172600	-0.00010900	0.00023200	0.00029300	0.00030800	0.00031200
30-49	0.00022900	-0.00002600	-0.00021400	0.00005100	-0.00001100	0.00000047	0.00000300	0.00000300	0.00000300
50-99	0.00006000	-0.00000800	-0.00005800	0.00001300	-0.00000400	-0.00000054	0.00000000	0.00000014	0.00000018
100-199	0.00002200	-0.00000300	-0.00002100	0.00000500	-0.00000100	-0.00000025	-0.00000005	0.00000000	0.00000001
> 200	0.00000700	-0.00000088	-0.00000700	0.00000100	-0.00000044	-0.00000008	-0.00000002	0.00000000	0.00000000

* No. of cows.

Source: Author's estimates.

However, it is important to note that since $S(\tilde{\mathbf{p}})$ is a relative measure, all that one can say is that the IV-GCE model yields superior estimates, increasing by 0.3 per cent the overall information content of the estimated model by comparison with the stationary version of the model. Table 5.7 gives the estimates for the IV-GCE model for Poland. These estimates deviate only slightly from the estimates derived with a simple GCE approach; slight gains in information are still obtained within each class. In order to ascertain the non-stationary effects for Poland, the elasticities capturing the effect of an increase in the number of dairy farms in each size categories at time (t) on the Markov transition probabilities were computed first (see Table 5.8). The effects are very small for the large farm-size classes, as indicated by the abundance of zero cells in the bottom right corner of the matrix. The elasticities are consistent with respect to exit and re-entry size classes. An increase in the number of dairy farms in each size category at time (t) is accompanied by a decline in the number of exit and/or by increase in re-entry. From our results the most meaningful effects in terms of farm growth are found for the category with 10-29 cows.

Tables 5.9, 5.10 and 5.11 show the calculated elasticities measuring the effect of a unit change in each covariate on the transition probabilities, given that all other variables are kept constant. The trend has a positive impact on exit and a negative impact on re-entry. In addition, there is an increase over time in the farms with 10-29 cows, underlining that this farm size class is becoming more important over time. This fits in with Sznajder (2002: 253) who shows that in order to have full return from the engaged capital, including rent of the land (land capital), Polish dairy farms need to have a heard of at least 10-15 dairy cows. This suggests that the minimum efficient size of dairy farms, minimizing the per unit costs, or the minimum locus on the long-run average costs level for farms is at a herd size of 10 cows or more. Our findings even go beyond this, implicitly suggesting an L-shaped average cost curve, since the milk output price is fuelling an increase in farm size, starting for farms with more than 10 cows and upward. For example, a unit increase in the milk output price increases by 0.04 per cent the probability of dairy farms with 10-29 cows scaling-up by one size class. This finding is also supported by the effect of the price of concentrates, which has a positive effect in scaling-up for farms with more than 10 cows.

This fits in with Sznajder (2002: 253) who shows that Polish dairy farms in order to have full return from the engaged capital, including rent of the land (land capital), need to have a dairy cow stock of at least 10-15 dairy cows. This suggests that the minimum efficient size of dairy farms, minimizing the per unit costs, or the minimum locus on the long-run average costs level for farms is at a herd size of 10 cows or more. Our findings even go beyond this implicitly suggesting an L-shaped average cost curve since the milk output price is fuelling an increase in farm size starting for farms with more than 10 cows and upward. For example a unit increase in the milk output price increases the probability by 0.04 per cent of dairy farms with 10-29 cows to scale-up by one size class. This finding is also supported by the effect of the compound feed price which has a positive effect in scaling up for farms endowed with more than 10 cows.

Table 5.12 presents the cumulative effects of a unit change in each covariate on the total number of dairy farm in each size category at time (t+1). The trend impact found implies that over time there is a contraction in the farms with 1-9 cows and an increase in the remaining farms, except for those in the largest farm-size category. An increase in the producer's cow milk price has a negative impact on exit and a positive impact on all farm size categories, particularly for the farms with 50-99 cows. Conversely, an increase in the price of concentrates has a positive impact on exit and a negative impact for all farm size categories, except for the farms with 3-9 cows.

Table 5.12 Cumulative effects of each covariates z_{tn} for the number of dairy farms y_k

Classes*	0	1	2	3-9	10-29	30-49	50-99	100-199	>200
z_{t1}	0.0160	-0.0089	-0.0055	-0.0034	0.0034	0.0048	0.0017	0.0005	-0.0034
z_{t2}	-0.0389	0.0194	0.0241	0.0005	0.0008	0.0099	0.0418	0.0191	0.0082
z_{t3}	0.0179	-0.0050	-0.0217	0.0043	-0.0064	-0.0190	-0.0457	-0.0203	-0.0041

Source: Author's estimates. * No. of cows.

From the estimated Markov transition probabilities it was possible to compute several indicators based on the Markov equilibrium distribution of firms defined by Adelman (1958: 895-896). Following the Markov formalism, the transition probability matrix is constituted by several absorbing and non-absorbing states. Typically, an absorbing state is defined as a state from which it is impossible to leave; i.e. $p_{lk} = 1$. A Markov chain is absorbing if it has at least one absorbing state and it is possible for every non-absorbing state to reach an absorbing state. Non-absorbing states are all the other Markov states from which it is possible to leave; i.e. $p_{lk} \neq 1$. In this way it was possible to determine the mean number of years in each Markov state before absorption, as well as the probability that a non-absorbing Markov state will end up in a particular absorbing state.

In order to derive the above mentioned indicators it was first assumed that there were two absorbing states for l, k = 0, K implying that dairy farms leaving the sector will not re-enter the sector and dairy farms in the largest farm size class will not leave the class. The logical consequence is that in equilibrium the non-absorbing Markov states can only be absorbed by the exit class (l, k = 0) and by the largest size class (l, k = K). This is clearly a convenient assumption for the problem at hand, although it may well approximate the true situation, given that a very small fraction of dairy farms out of the sector have been allowed to re-enter and also that the majority of the farms in the largest farm size class have remained in that class.

Two sub matrixes had to be recovered, starting from the original estimated transition probability matrixes[54]. The first matrix was simply obtained by deleting from the original Markov transition probability matrix the two rows associated with p_{0k} and p_{Lk} as well as the two columns associated with p_{l0} and p_{lK}. This yields a matrix of dimension $(L-2)\times(K-2),\ \forall l,k=1,...,K$. The newly obtained sub transition probability matrix was then subtracted from the identity matrix and inverted. This yielded the number of years in each transient state for each non-absorbing state as given in Table 5.13.

The second sub matrix was composed of two columns associated with k = 0, K in which the two rows associated with l = 0, K were deleted; this led to a $(L-2)\times 2$ matrix, $\forall l,k=1,...,K$. The first sub matrix was then post multiplied by the second sub matrix in order to calculate the probabilities of absorption in the two absorbing states for each non-absorbing state as given in Table 5.14. From the estimates it appears that in equilibrium the majority of the dairy farms with 1 and 9 cows will leave the sector, whereas the dairy farms belonging to the remaining size states will continue in dairying. For example, in Poland about 66 per cent of the dairy farms with 30-49 cows will persist in the dairy sector, whereas 34 per cent are expected to leave the sector.

[54] Note that in this computation we considered for Poland the Markov transition probability matrix estimated using an IV-GCE approach since this model provided superior estimates.

Table 5.13 Estimated annual transient periods for Hungary and Poland

Hungary									
Classes *	1-2	3-9	10-19	20-29	30-49	50-99		Mean year	Rank
1-2	7.20	0.18	0.01	0.00	0.00	0.00		7.40	1
3-9	0.87	7.38	0.52	0.08	0.06	0.05		8.97	2
10-19	0.31	2.60	21.28	3.37	2.68	2.14		32.38	4
20-29	0.12	1.03	8.43	25.11	19.93	15.94		70.57	6
30-49	0.03	0.25	2.01	5.98	28.55	22.84		59.66	5
50-99	0.01	0.05	0.40	1.20	5.71	24.57		31.93	3
Poland									
	1	2	3-9	10-29	30-49	50-99	100-199	Mean year	Rank
1	8.10	1.75	0.86	0.61	0.44	0.41	0.42	12.58	1
2	2.77	6.20	3.04	2.15	1.55	1.44	1.47	18.62	2
3-9	1.21	2.71	10.53	7.44	5.36	4.99	5.09	37.33	4
10-29	0.87	1.94	7.52	19.53	12.35	10.68	10.78	63.67	6
30-49	0.52	1.16	4.51	11.72	19.41	16.39	16.47	70.16	7
50-99	0.17	0.39	1.50	3.90	6.47	22.13	22.16	56.72	5
100-199	0.03	0.08	0.30	0.78	1.29	4.43	24.43	31.34	3

Source: Author's estimates. * No. of cows.

Table 5.14 Estimated survival transition probabilities for Hungary and Poland

	Hungary			Poland	
Classes*	0	> 100	Classes[1)]	0	> 200
1-2	0.99995	0.00005	1	0.98335	0.01664
3-9	0.99792	0.00208	2	0.94119	0.05880
10-19	0.91431	0.08568	3-9	0.79643	0.20356
20-29	0.36225	0.63774	10-29	0.56882	0.43114
30-49	0.08625	0.91374	30-49	0.34115	0.65880
50-99	0.01725	0.98274	50-99	0.11372	0.88624
			100-199	0.02274	0.97723
Surviving farms in equilibrium		1104			81584

Source: Author's estimates. * No. of cows.

Finally, the estimated Markov transition probability matrixes were used to make several forecasts of the number of dairy farms in Hungary and Poland in the coming decade. In order to assess the predictive power of the estimated Markov models, projected values and actual values were first compared for a common base year (Table 5.15).

Table 5.15 Projected versus actual dairy farm size distribution

				Hungary 2003					
Classes*	1-2	3-9	10-19	20-29	30-49	50-99	>100		Total
Projected	13271.1	6779.4	1083.5	257.2	175.7	157.7	535.3		22259.8
Actual	13050.0	6840.0	980.0	280.0	190.0	170.0	490.0		22000.0
%	1.7	-0.9	10.6	-8.1	-7.5	-7.2	9.2		1.2
				Poland 2005					
Classes*	1	2	3-9	10-29	30-49	50-99	100-199	>200	Total
Projected	297649.3	143309.9	168273.8	63506.5	7495.0	1529.0	237.3	46.1	682046.9
Actual	316469.0	141659.0	170341.0	65959.0	4646.0	1098.0	139.0	44.0	700355.0
%	-5.9	1.2	-1.2	-3.7	61.3	39.2	70.7	4.7	-2.6

Source: Author's estimates. * No. of cows.

Table 5.16 Dairy far size distribution projections

	Hungary				Poland		
Classes*	2006	2009	2012	Classes[1)]	2006	2009	2012
1-2	7938.394	4831.373	2942.552	1	281856.169	198966.129	140577.695
3-9	4209.351	2605.103	1624.757	2	133397.377	107112.094	83286.578
10-19	914.786	832.413	745.712	3-9	156641.242	121296.396	94334.462
20-29	263.308	247.952	233.330	10-29	67310.100	66794.338	62819.860
30-49	194.600	197.201	198.150	30-49	8549.673	17708.721	23618.863
50-99	167.301	191.160	197.945	50-99	1749.371	4169.309	11848.696
>100	436.871	393.154	357.096	100-199	255.021	735.296	1474.247
				>200	49.560	64.635	77.623
Total	14124.610	9298.355	6299.543	Total	649808.513	516846.910	418038.023

Source: Author's estimates. * No. of cows.

For both countries, the estimated models predict reasonably well the total aggregate number of dairy farms, although for Poland the model has the tendency to overestimate the number of farms in the size class with 30-199 cows. This is mainly attributable to increases in the size class of 10-29 cows: a small fraction of farms in this farm size class can have a large impact on the other size classes. For Hungary, it is predicted that by 2009 there will be a decline in the total number of dairy farms of about 58 per cent with respect to 2003 figures. For Poland it is expected that by 2009 the total number of dairy farms will have declined by about 26 per cent with respect to 2005 figures (Table 5.16).

5.5 Conclusion

The present paper analysed the evolution of the dairy farm structure of Hungary and Poland during the post-socialist period. The focus was on determining how the farm structure has changed over time, as well as on predicting the likely structure in the coming decade. Several indicators concerning farm mobility and farm survival were addressed. In addition it was tested whether farm size evolution was dependent on economic, policy and environment variables and the impact and directions of these dependencies was determined.

An innovative GCE estimation procedure was applied, which was able not only to cope with the encountered data limitations typical for CEECs but also to take into account prior information about farm structure and mobility. Moreover, the modelling approach enabled the detection of the impact of several covariates (policy, technological change) on the transition probabilities (non-stationary model estimated with an IV-GCE-estimator). For Poland, the IV-GCE yielded superior estimates as compared to the stationary GCE model; most of the non-stationary effects were captured by the small and medium size classes. It appeared that most of the dynamic adjustments could be explained in those farm size classes.

The projections show that the number of dairy farms will continue to decline in the coming decade, although with an increase in the number of farms of medium and large size. In Hungary, it is farms of these sizes that will increase, particularly farms with 30-99 cows, whereas in Poland, the increase will be in farms with more than 30 cows. For Hungary, this is in line with the ongoing restructuring of the former large-scale collective farms which will continue with the dismantling of the largest units into medium-size viable units. On the other hand, in Poland a consolidation process is expected, where small dairy farms (i.e. semi-subsistence farms) will continue to exit from the sector.

The estimated mean number of years before the small subsistence dairy farms with 1-2 cows leave the dairy sector is approximately 7 years for Hungary and 15 years for Poland. In addition, only dairy farms with at least 10-29 cows are expected to survive at the Markov equilibrium. The exit from the sector of the subsistence dairy farms is predicted to proceed more slowly in Poland than in Hungary, with the latter country facing more drastic farm restructuring.

The predicted transition from a subsistence farming style to a more modern and specialized farm structure is not an obvious and automatic step. Most of the time, exiting is not an option for farmers in CEECs, simply because the industrial or service sectors are not able to absorb the redundant unskilled labourers, given the difficult economic environment (Petrick and Weingarten (2004: 6)). In Poland, according to the last (2002) Agricultural Census, about 1 million of individual farmers have failed to find a job, thus fuelling the so-called "hidden unemployment"[55]. In addition, from 1 May 2006, Polish farmers have been entitled to receive direct payments following a simplified framework which allocates the premiums per hectare of land. Direct payments consist of a per hectare Single Area Payment System (SAPS) and supplemental eligible crop area payments. The eligibility criteria for the SAPS require that farmers own over 1 hectare of arable land, provided that the arable "plot" is no smaller than 0.1 hectare (USDA (2005: 5)). In the Malopolska region, where the average farm size is about 2.10 hectares and about 45.5 per cent of the farming population receive income from pension schemes, disability benefits and other social security, the distribution of direct payments may act as an additional social support, keeping subsistence and semi-subsistence farming in business. Petrick and Weingarten (2004: 5-7) indicate that at least for Poland, subsistence farms constitute a social buffer to rural unemployment. Changes in employment conditions outside agriculture, as well as changes in welfare payments and health insurance provisions were not taken explicitly taken in to account in the present analysis and could lead to different results, in particular for the subsistence sector.

Overall, these findings confirm that in the near future the dairy farm structure of Hungary and Poland is likely to converge to a European dairy farming style. The concentration of land in fewer but more efficient farms depends on the mediating role of a well-defined and functioning land market. When lacking, this not only hampers efficient land allocation, but also limits the access to capital (land credit, mortgage) and hence investments.

[55] Zmija and Tyran (2004: 75) Note that in Poland, the owners and holders of farms with an area equal to or exceeding 2 hectares cannot be registered as unemployed.

Moreover, as Lyson and Welsh (1992), DuPuis (1993), and Lyson and Gillespie (1995) have postulated, the size structure of dairy farming is related to changes in the milk market. The entry of large-scale foreign investors with mass production dairy-processing facilities, for example, is usually accompanied by a decline in the number of small units unable to comply with the quality requirements imposed, and by an increase in the number of large-scale producers. It was beyond the scope of the current research to take account of the impact of downstream (and upstream) industries on the farm size distribution (for more details about the effect of FDI on small suppliers see Dries and Swinnen (2004: among others).

Appendix 5.1

Prior transition probabilities

Table A5.1 Prior transition probability for Hungary

Classes	0	1-2	3-9	10-19	20-29	30-49	50-99	> 100
0	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
1-2	0.40000	0.59000	0.01000	0.00000	0.00000	0.00000	0.00000	0.00000
3-9	0.35000	0.05000	0.59000	0.01000	0.00000	0.00000	0.00000	0.00000
10-19	0.08000	0.00000	0.05000	0.85000	0.02000	0.00000	0.00000	0.00000
20-29	0.00000	0.00000	0.00000	0.05000	0.85000	0.10000	0.00000	0.00000
30-49	0.00000	0.00000	0.00000	0.00000	0.03000	0.85000	0.12000	0.00000
50-99	0.00000	0.00000	0.00000	0.00000	0.00000	0.03000	0.85000	0.12000
> 100	0.12000	0.00000	0.00000	0.00000	0.00000	0.00000	0.03000	0.85000

Source: Author's computations.

Table A5.2. Prior transition probability for Poland

Classes	0	1	2	3-9	10-29	30-49	50-99	100-199	> 200
0	0.99240	0.00000	0.00000	0.00000	0.00590	0.00090	0.00070	0.00009	0.00001
1	0.15000	0.80000	0.05000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.10000	0.05000	0.80000	0.05000	0.00000	0.00000	0.00000	0.00000	0.00000
3-9	0.05000	0.00000	0.05000	0.84000	0.05000	0.00660	0.00300	0.00040	0.00000
10-29	0.00000	0.00000	0.00000	0.05000	0.90000	0.04987	0.00010	0.00003	0.00000
30-49	0.00000	0.00000	0.00000	0.00000	0.05000	0.90000	0.04989	0.00011	0.00000
50-99	0.00000	0.00000	0.00000	0.00000	0.00000	0.02000	0.93000	0.05000	0.00000
100-199	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01000	0.95000	0.04000
> 200	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.99999

Source: Author's computations.

Appendix 5.2

The Lagrangian problem for the IV-GCE estimator

For simplicity, scalar notation is used. The corresponding Agrarian for the IV-GCE estimator as discussed in the main part of the text is given by:

$$\mathbf{L} = -\sum_l \sum_k p_{lk} \ln(p_{lk}/q_{lk}) - \sum_t \sum_k \sum_h w_{tkh} \ln(w_{tkh}/u_{tkh}) + \tag{II.1}$$

$$+ \sum_n \sum_k \tilde{\lambda}_{nk} \left[\sum_t z_{tn} y_{tk} - \sum_t \sum_l z_{tn} x_{tl} p_{lk} + \sum_t \sum_h z_{tn} V_{tkh} w_{tkh} \right] +$$

$$+ \sum_l \tilde{\mu}_l \left[1 - \sum_k p_{lk} \right] +$$

$$+ \sum_t \sum_k \tilde{\rho}_{tk} \left[1 - \sum_h w_{tkh} \right]$$

Through the gradient of the Lagrangian function with respect to the unknown to be estimated, the optimal first order conditions are given by:

$$\frac{\partial \mathbf{L}}{\partial p_{lk}} = \ln(p_{lk}/q_{lk}) + 1 - \sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} - \tilde{\mu}_l = 0 \tag{II.2}$$

$$\frac{\partial \mathbf{L}}{\partial w_{tkh}} = \ln(w_{tkh}/u_{tkh}) + 1 - \sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh} - \tilde{\rho}_{tk} = 0 \tag{II.3}$$

$$\frac{\partial \mathbf{L}}{\partial \lambda_{nk}} = \sum_t z_{tn} y_{tk} - \sum_t \sum_l z_{tn} x_{tl} p_{lk} + \sum_t \sum_h z_{tn} V_{tkh} w_{tkh} = 0 \tag{II.4}$$

$$\frac{\partial \mathbf{L}}{\partial \mu_l} = 1 - \sum_k p_{lk} = 0 \tag{II.5}$$

$$\frac{\partial \mathbf{L}}{\partial \rho_{tk}} = 1 - \sum_h w_{tkh} = 0 \tag{II.6}$$

Taking the first order condition (a.2) and bringing terms to the right hand side as a function of $\ln(p_{lk}/q_{lk})$ yields:

$$\ln(p_{lk}/q_{lk}) = -1 + \sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} + \tilde{\mu}_l \tag{II.7}$$

Taking the exponent yields:

$$p_{lk} = q_{lk} \exp\left(-1 + \sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} + \tilde{\mu}_l \right) \tag{II.8}$$

From the Markov problem regularities conditions $\sum_k p_{lk} = 1$ is required, which yields:

$$\sum_k q_{lk} \exp\left(-1 + \sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} + \tilde{\mu}_l \right) = 1 \qquad (II.9)$$

Through this normalization the $\tilde{\mu}_l$ Lagrange multiplier is lost and the IV-GCE Markov transition probabilities are finally recovered:

$$\tilde{p}_{lk} = \frac{q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} \right)}{\sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} \right)} \qquad (II.10)$$

Since over all λ_{nk} Lagrange multipliers and corresponding restrictions one is redundant it is therefore convenient to normalize the expression in (a.10) by $\tilde{\lambda}_{nk} = 0$ for each covariate $n = 1,\dots, N$. This provides the following scaled solutions:

$$\tilde{p}_{lk} = \frac{q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} \right)}{q_{l1} + \sum_{k=2}^{K} q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl} \right)} \qquad (II.11)$$

In a similar way it is possible to recover the proper probabilities related to the error term. Taking the first order condition (a.3) and bringing terms to the right hands side as a function $\ln(w_{tkh} / u_{tkh})$ yields:

$$\ln(w_{tkh} / u_{tkh}) = -1 + \sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh} + \tilde{\rho}_{tk} \qquad (II.12)$$

Taking the exponent yields:

$$w_{tkh} = u_{tkh} \exp\left(-1 + \sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh} + \tilde{\rho}_{tk} \right) \qquad (II.13)$$

From the entropy proper probabilities it is required that $\sum_h w_{tkh} = 1$, which yields:

$$\sum_h u_{tkh} \exp\left(-1 + \sum_n \tilde{\lambda}_{nk} z_{tn} V_{tkh} + \tilde{\rho}_{tk} \right) = 1 \qquad (II.14)$$

Again through the normalization one constraint is lost and the IV-GCE error proper probabilities are finally recovered:

$$w_{tkh} = \frac{u_{tkh} \exp\left(\sum_{n} \tilde{\lambda}_{nk} z_{tn} V_{tkh}\right)}{\sum_{h} u_{tkh} \exp\left(\sum_{n} \tilde{\lambda}_{nk} z_{tn} V_{tkh}\right)} \qquad (II.15)$$

Appendix 5.3

Probability elasticities

Here the probability elasticities for the IV-GCE estimator are derived. Three types of impact elasticity are derived: the probability elasticity for an increase in x_{lt}, the probability elasticity for increase in the z_{tn} covariates, the cumulated probability elasticities on the total round count y_{kt} for an increase in the z_{tn} covariates.

- The marginal effect on p_{lk} for a change in x_{tl} is given by:

$$\frac{\partial \tilde{p}_{lk}}{\partial x_{lt}} = \frac{\left(q_{l1} + \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)\right) \cdot q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right) \sum_n \tilde{\lambda}_{nk} z_{tn}}{\left(q_{l1} + \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)\right)^2} + \quad (III.1)$$

$$- \frac{\sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right) \cdot \sum_n \tilde{\lambda}_{nk} z_{tn} \cdot q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)}{\left(q_{l1} + \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)\right)^2}$$

$$\frac{\partial \tilde{p}_{lk}}{\partial x_{lt}} = \tilde{p}_{lk} \sum_n \tilde{\lambda}_{nk} z_{tn} - \tilde{p}_{lk} \sum_k \sum_n \tilde{p}_{lk} \tilde{\lambda}_{nk} z_{tn} = \tilde{p}_{lk} \left[\sum_n \tilde{\lambda}_{nk} z_{tn} - \sum_k \sum_n \tilde{p}_{lk} \tilde{\lambda}_{nk} z_{tn}\right]$$

Expressing the effect on p_{lk} for a change in x_{tl} in terms of elasticity at sample average yields:

$$\frac{\partial \tilde{p}_{lk}}{\partial x_{tl}} \cdot \frac{\bar{x}_{tl}}{\tilde{p}_{lk}} = \bar{x}_{tl} \left[\sum_n \tilde{\lambda}_{nk} \bar{z}_{tn} - \sum_k \sum_n \tilde{p}_{lk} \tilde{\lambda}_{nk} \bar{z}_{tn}\right] \quad (III.2)$$

- The marginal effect on p_{lk} for a change in z_{tn} is given by:

$$\frac{\partial \tilde{p}_{lk}}{\partial z_{tn}} = \frac{\left(q_{l1} + \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)\right) \cdot q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{lt}\right) \cdot \tilde{\lambda}_{nk} x_{tl}}{\left(q_{l1} + \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)\right)^2} + \quad (III.3)$$

$$- \frac{q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right) \cdot \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right) \cdot \tilde{\lambda}_{nk} x_{tl}}{\left(q_{l1} + \sum_k q_{lk} \exp\left(\sum_n \sum_t \tilde{\lambda}_{nk} z_{tn} x_{tl}\right)\right)^2}$$

$$\frac{\partial \tilde{p}_{lk}}{\partial z_{tn}} = \tilde{p}_{lk}\tilde{\lambda}_{nk}x_{tl} - \tilde{p}_{lk}\sum_k \tilde{p}_{lk}\tilde{\lambda}_{nk}x_{tl} = \tilde{p}_{lk}x_{tl}\left[\tilde{\lambda}_{nk} - \sum_k \tilde{p}_{lk}\tilde{\lambda}_{nk}\right]$$

Expressing the effect on p_{lk} for a change in x_{lt} in terms of elasticity at sample average yields:

$$\frac{\partial \tilde{p}_{lk}}{\partial z_{tn}} \cdot \frac{\bar{z}_{tn}}{\tilde{p}_{lk}} = \bar{z}_{tn}\bar{x}_{tl}\left[\tilde{\lambda}_{nk} - \sum_k \tilde{p}_{lk}\tilde{\lambda}_{nk}\right] \quad (III.4)$$

- The cumulated effect of each covariate z_{tn} on the total round count y_{tk} is given by

$$\sum_l \frac{\partial \tilde{p}_{lk}}{\partial z_{tn}} \cdot \bar{x}_{tl} = \sum_l \tilde{p}_{lk}\bar{x}_{tl}^2\left[\tilde{\lambda}_{nk} - \sum_k \tilde{p}_{lk}\tilde{\lambda}_{nk}\right] \quad (III.5)$$

That in terms of elasticities translates into:

$$\left(\sum_l \frac{\partial \tilde{p}_{lk}}{\partial z_{tn}} \cdot \bar{x}_{tl}\right)\frac{\bar{z}_{tn}}{\bar{y}_{tk}} = \frac{\bar{z}_{tn}}{\bar{y}_{tk}}\left[\sum_l \tilde{p}_{lk}\bar{x}_{tl}^2\left[\tilde{\lambda}_{nk} - \sum_k \tilde{p}_{lk}\tilde{\lambda}_{nk}\right]\right] \quad (III.6)$$

CHAPTER 6

General Discussion and Conclusions

6.1 Introduction

In this chapter, the papers that make up the body of the thesis are discussed as a whole. Figure 6.1 relates the different chapters to their main objectives. The research objectives were addressed by relying on a positive approach using notions from neoclassical production theory and aggregate country-level data. The thesis was in two parts, as described in section 1.2. The first part dealt with sectoral economic analysis for several Central Eastern European Countries (CEECs). Chapter 2 investigated the performance of the agricultural sector in the decade after transition for several CEECs. Particular emphasis was given to testing the following hypotheses: whether the sectoral agricultural performance worsened after transition and whether countries characterised by large-scale farming performed better than countries with small-scale farming during a period of unstable economic conditions and missing markets. Chapter 3 focused on the transition-induced adjustments to the mix of agricultural outputs for Hungary and Poland. Output substitutability measures were recovered, which were helpful when examining the extent of allocative inefficiency.

After having focused on the agricultural sector of the CEECs in the first part of the thesis, in the second part the dairy sector was analysed for two of the most important dairy producers among the CEECs which joined the European Union (EU) in 2004: Hungary and Poland. Chapter 4 modelled the dairy and beef supplies for Poland and Hungary following a restricted dual profit-function approach. The model was able to model medium-run dynamics, using a partial adjustment scheme for the quasi-fixed inputs. Whereas chapter 4 followed a sectoral approach, chapter 5 focused on analysing the underlying structural change in the dairy farm size distribution. More precisely, the dairy farm size dynamics were analysed using a Markov chain approach that enabled several projections to be made of the most likely dairy farm structure for the coming decade. The effects of several policy variables on farm structure were also modelled.

This final chapter is built upon the previous chapters. First, it provides a discussion of several limitations encountered in the data (6.2.1). Second, it discusses the main methods (6.2.2) used. Third, it delivers an overview/synthesis of the results (6.3). Fourth, elements for further research are elaborated (6.4). The chapter closes with a list of the main conclusions (6.5).

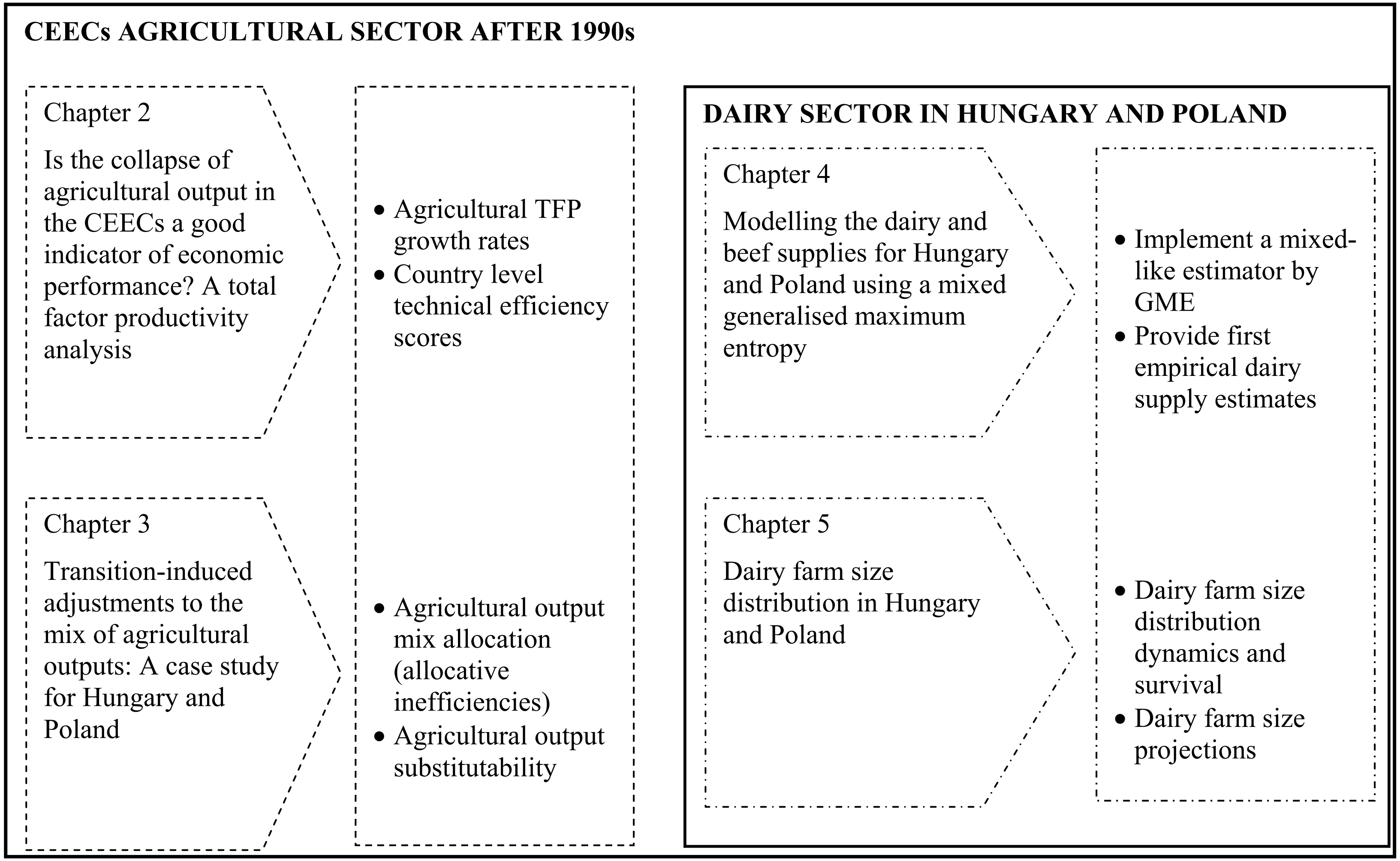

Figure 6.1 Flow chart summarising the chapters of the thesis.

Source: Author's presentation.

6.2 Data and methods

This section first briefly recapitulates the main data characteristics of the quantitative information used in the thesis. In so doing it also discusses the most important issues and limitations that were faced. In the second part, the methodological pillars on which the thesis rests are discussed separately.

6.2.1 Data and caveats

The regime shift that typified transition economies in Central and Eastern Europe undermined the conventional requirements for economic modelling[56]. During reform, not only the political and institutional system changed, but also the way statistics were organised (Hallam (1998)). Thus data before transition refer to a political, economic and institutional system that differs from the post-socialist period, since both periods represent two separate economies, distinguished by their "economic point of view." In addition, from a "statistical point of view" discrepancies due to measurement errors are observed in the literature when comparing data before and after transition (Blangiewicz, Bolt and Charemza (1993), Hallam (1998)). Whereas during the centrally planned regime that prevailed prior to transition there was a tendency to overstate production on the output side and consumption on the input side, during the socialist regime no allowance was made for losses on the output side. Inputs were often applied wastefully and the quantities of inputs supplied were often exaggerated. During the post-transition new market economy, however, there was a tendency to underreport the production levels. Small private enterprises were excluded from the reporting system and there was also no incentive to overstate statistics on production.

During the time the research was being done for this thesis there was no access to sufficient and reliable micro-level data. Only aggregate country-level data could be exploited. As there was insufficient data from the post-socialist period to be able to apply conventional estimation procedures, use was made of different sources of information. The different sources of information embraced sample information (SI) and non-sample information (NSI). The former contains information provided by the sample data sourced from Eurostat, FAO,

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[56] Some of the most important requirements for economic modelling are: one-to-one correspondence, efficiency, homogeneity, and availability: see Blangiewicz, Bolt and Charemza (1993).

OECD and national statistical offices. The latter included information that was available prior to the sampling process.

The time frame of the SI was after the transition reform, as discussed in chapter 1. Most of the data were time series, although in chapters 2 and 5 it was possible to use repeated observations over the same units for a certain number of periods. Chapter 2 relied directly upon panel data.

NSI differed in its sources (theory, previous economic analysis, statistics, and other sources) as well as in its type in terms of constraints ("exact" equality constraints, "inexact" equality constraints, and inequality constraints). The quality of NSI had to be checked before estimation. First, NSI had to be surveyed and collected from sources external to sample data. Second, a prior value had to be formed for parameters, production measures (e.g. elasticities, responses) as well as for more complex relationships. Then the compatibility of NSI with SI in terms of units of measure also had to be checked. The sources and type of data used in the thesis are summarised in Table 6.1.

In the remaining part of this section, several data problems and issues related to the quality of the data are considered with reference to individual chapters. In chapters 2 and 3 it was found that land at country level did not show significant variation over time and its inclusion created problems in the estimation because of the collinearity with the intercept term. Land input was therefore excluded from the models estimated in chapters 2 and 3. Another reason supporting this decision was that other researchers have found that land input has not been a limiting production factor in most developing countries and transition economies (Hayami and Ruttan (1970), Kawagoe, Hayami and Ruttan (1985), Carter and Zhang (1994)). Bezlepkina (2004) found a zero shadow price of agricultural land for Russia.

Data quality (see for a detailed treatment Griliches (1986)) affected the methodology used in chapter 4. Lack of certainty about the correctness and definition of the animal feed variable[57] might have led to systematic errors of measurement affecting the computation of variable profits.

Such errors could have affected the full estimates of the system because of the interactions between the different sources of noise in the equations which were jointly estimated as a system.

[57] The animal feed variable was derived by aggregating the main coarse grains used for animal feed in agriculture (i.e. not only for dairy)

Table 6.1 Summary of sample and non-sample information

Chapter	Source of SI	Type of SI	Source of NSI	Type of NSI (restriction)
2	FAO[1)]	Panel data for the CEECs[4)], 1993–2002	*Theory*	
			-CRS[5)] (ex-ante)	Exact equality
			-Input concavity (ex-post)	Inequality
			-Input monotonicity (ex-post)	Inequality
3	FAO	Time series data for Hungary and Poland, 1991–2001	*Theory*	
			-Elasticities sign	Inequality
			-Input homogeneity	Exact equality
			-Input monotonicity	Inequality
			-Revenue maximisation	Inexact equality
			Previous economic analysis	
			-Magnitude of elasticities	Inexact equality
4	FAO, OECD[2)], national statistical offices	Time series data for Hungary and Poland, 1990–2002	*Theory*	
			-Elasticities sign	Inequality
			-Price convexity	Inequality
			Previous economic analysis	
			-Magnitude of elasticities	Inexact equality
			-Milk yield increase	Inexact equality
			Other sources	
			-Milk response to dairy cow stock	Inexact equality
			-Monotonicity in quasi-fixed inputs (supply eq.)	Inexact equality
			-Price monotonicity (stock eq.)	Inexact equality
5	Eurostat[3)], national statistical offices	Aggregate data on the size distribution of dairy farms (Hungary 2000 and 2003, Poland 1995–2005)	*Other sources*	
			-Dynamic farm size growth	Embedded as a prior in the estimation
			Statistics	
			-Contemporaneous correlation	Exact equality

[1)] FAO = Food and Agriculture Organization of the United Nations; [2)] OECD = Organization for Economic Co-operation and Development; [3)] Eurostat is the statistical office of the European Commission; [4)] The ten CEECs considered in this analysis are Bulgaria, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia; [5)] CRS is the acronym for Constant Return to Scale.

Source: Author’s presentation.

In this way, a simplified system of supply equations was estimated, rather than a complete system including the profit function. By doing so, some loss in efficiency was accepted in order to avoid a bias. This also avoided further decreasing the degrees of freedom and multicollinearity problems associated with the second order or cross product terms of the dual profit function.

In chapter 4 a distinction had to be made between commercial and subsistence milk productions. There was evidence from the literature that peasant agriculture (farming in which farmers predominantly obtain their livelihood from the land, relying on family labour) is appreciable in the agricultural production of many CEECs[58], particularly Poland (Abele and Frohberg (2003)). For Poland, therefore, the dairy output and dairy cattle stock in subsistence farming were deducted from national aggregate dairy output and dairy cattle stock, so that only data for the commercial dairy sector were considered.

In chapter 5, when analysing the dairy farm size distribution, only the total aggregate number of dairy farms classified according to their dairy cow herd size was available for a certain number of years. Thus no aggregate data were available for the number of farms that changed size class. The underlying farm size dynamic could not therefore be extrapolated solely from the data. Prior information on farm size mobility helped in recovering the true underlying situation. In addition, for Hungary it was only possible to exploit SI for two years, as compared to Poland where 11 years (i.e. 10 transitions) could be exploited.

6.2.2 Methodological issues

Sample versus non-sample information

When drawing inferences from sample data, practitioners of econometrics implicitly use some sort of NSI. For example, assumptions are made about the best variables describing the system under scrutiny, in approximating the underlying dynamic data-generating structure, in making stochastic assumptions. The violation of these assumptions is often the reason for rejecting the initial “maintained hypotheses” (Theil and Goldberger (1961), Conway and Mittelhammer (1986)). For example, if the expectation is that a regression slope

[58] For example, Juhasz (1991: 403) reported that in 1987 in Hungary 75.9 percent of all vegetables and 75.7 percent of all potatoes were produced by small farms. Mathijs and Noev (2004: 78) found that 39 percent of all individual farmers were subsistence farming, representing about 5 percent of the total cultivated agricultural land. Van Zyl, Miller and Parker (1996: 35) discovered that for Poland the optimal farm size should lie between 10 and 20 ha, although the average area of private farms exceeding 1 ha of agricultural land was about 7.5 ha in 2004 PCSO (2005: 240).

will be positive and the estimated model returns a negative regression slope, the researcher is tempted to modify the initial "maintained hypothesis" and to estimate ex post a different model specification based solely on sample data.

Several "classical" and "non-classical" econometric approaches allow directly incorporating in the estimation the causes of rejecting the initially "maintained hypothesis", i.e. NSI (using classical terminology) or prior information (using Bayes terminology). In the classical approaches, worth mentioning is the pioneering work of Durbin (1953), in which extraneous information about one of the regression coefficients was incorporated during estimation. The combination of SI and NSI was then formalized in the Theil-Goldberger mixed estimation (TGME)[59] (Theil and Goldberger (1961), Theil (1963)). Mittelhammer and Conway (1988) proved the quadratic-risk inadmissibility of the TGME and introduced the prior integrated mixed estimator. Nowadays within a sampling theory contest (i.e. "classical" or "frequentist" contest) when the econometrician is certain of the NSI, the restricted least square is used; when the econometrician is uncertain[60] of the NSI, a sampling theory estimator with stochastic restrictions rested on the restricted least square is used. Within the class of "classical" approaches there is also an inequality restricted estimator available for incorporating external source to sample data. For an in dept treatment of these "classical" estimators see Judge, Hill, Griffiths, Lütkepohl and Lee (1988: 812-830).

Other alternative techniques that allow external source of information to be incorporated in the estimation are the Bayesian (Zellner (1971), Koop (2003), Lancaster (2004), Geweke (2005)) and maximum entropy (ME) approaches (Golan, Judge and Miller (1996), Mittelhammer, Judge and Miller (2000)). Both approaches are based on probability statements about the unknown parameters to be estimated. However ME criteria maximize a certain informational-objective function subject to certain "conservation laws" representing the underlying system without the need to specify a likelihood function as done in the Bayesian class of estimators. Zellner (1988) formally showed the connection between the Bayes and cross-entropy information processing rule since they both translate prior and SI (i.e. "conditional" density for the Bayes) into posterior information.

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[59] Following Kmenta (1986: 497-500), the "mixed" estimator can be seen as a method able to combine prior information about one or more of the regression coefficients with the information provided by the data. One of the controversies of the TGME is its ambiguity of treating parameters as fixed in the regression and as random in deriving the mixed estimation formula.

[60] Frequently the external source of information to sample data is vague, so it cannot be introduced in an exact way (Vijn (1980), Toutenburg (1982)).

In this thesis large use was made of external information to sample data mostly relying on entropy methods. Entropy methods are well suited when there is not enough information to estimate a satisfactory likelihood function using Bayesian approaches[61]. The inclusion of NSI allowed to directly incorporating in the estimation process the assumptions that in conventional approaches cause to reject the "maintained hypothesis." In this way, the specification search, often called "data mining" in the literature, was implicitly avoided (Lovell (1983)). In addition the use of NSI is known to improve the efficiency of the final estimates whereas the unbiasedness is more difficult to prove since it lies in the basis for the prior information.

One of the interesting methodological contributions of this thesis has been in developing restrictions that could be incorporated as constraints in the estimation, combining SI with NSI in a transparent and consistent way, relying on entropy criteria (see chapters 3, 4 and 5). Complex linear and non-linear stochastic restrictions were formulated in order to introduce NSI in the estimation. The restrictions were specified so as to directly characterise the uncertainty attached to each restriction, implicitly attributing a "weight" to them during the optimisation procedure. In addition, when restrictions contain not only parameters but also data, they cannot hold exactly at each data point and therefore an additional noise term has to be introduced. In so doing the noise was parameterised, considering the sample scale of the variable included in the restrictions. The underlying principle followed here, is that imposing inexact NSI may be better than ignoring all information external to sample data and may also be better than assuming exact NSI.

Maximum entropy econometrics

In this thesis use was made of information entropy econometrics (see chapters 3, 4, and 5) to estimate economic models characterised by "ill-posed" and "ill-conditioned" problems. Maximum entropy (ME) is based on the entropy-information concept developed by Shannon (1948). The ME formalism has been successively applied to solve econometric problems by Golan, Judge and Miller (1996), Fomby and Carter Hill (1997), and Mittelhammer, Judge and Miller (2000). The criteria used in this thesis derive from the generalisation of the ME criterion to accommodate for the constraints of noisy data. The

[61] An alternative to the entropy estimator used in the Thesis is represented by the Bayesian method of moments (BMOM) of Zellner (1996). The BMOM differs from traditional Bayesian econometrics because it does not need to specify a prior density and the likelihood function.

generalised maximum entropy (GME) estimator was used in chapters 3 and 4, and the generalised cross entropy (GCE) estimator was used in chapter 5.

The GME/GCE estimators belong to the information theory class of estimators. Information theory estimators derive probability distribution over a reparameterised parameter (and also noise) support, making minimal distributional assumptions (Golan, Judge and Miller (1996), Mittelhammer, Judge and Miller (2000)). The main difference between GME and GCE approaches is that GCE allows the direct incorporation of prior information in the criterion to be minimised. In this way GCE minimises the distance between the prior assessment of a parameter and the estimated value. In chapters 3 and 4, NSI was introduced in the estimation procedure through additional constraints to the data consistency constraint. In chapter 5, NSI from dairy farm dynamics could be incorporated directly into the GCE criterion as a prior. The risk of introducing incorrect prior information is effectively discounted by the entropy estimators, which are always subject to moment consistency constraint represented by the data so that the final estimates will not stray too far from the original data (Golan, Judge and Miller (1996: 142)).

The properties of the GME/GCE estimators are discussed in detail in the classic ME econometrics references of Golan, Judge and Miller (1996) and Mittelhammer, Judge and Miller (2000). Here we only briefly recall some of the most important characteristics of the GME/GCE that were helpful in dealing with the problems at hand. First, the GME/GCE estimators are able to recover estimates even under “negative” degrees of freedom. Secondly, they easily allow for NSI to be included in the estimation procedure. Thirdly, since they use each piece of observation in the data rather than moment conditions, they are a more suitable and efficient estimator for small sample than the more conventional estimators. Fourthly, they are known to be less influenced by outliers as compared to traditional estimators because of the implicit weighting in the criterion between signal and noise. Finally, they are robust estimators, even when disturbances are not normally distributed and/or the exogenous variables exhibit high condition numbers.

Statistical inference

A reader of this thesis who is familiar with classical econometrics may find chapters 3–5 rather weak in terms of statistical inference, since the conventional statistics were generally not computed and reported. This was intentional. Making statistical inference when the degrees of freedom are low or even negative weakens the power of classical statistical tests based on the behaviour of statistics in repeated sampling (Leamer (1983), McCloskey (1985), Altman (2004)).

Statistical inference for the GME/GCE estimators rests on classical sampling theory (Mittelhammer and Cardell (1997), Golan, Perloff and Shen (2001)), although their estimates are derived through probability statements as done in the Bayesian approaches. In order for the GME/GCE estimators to be consistent and asymptotically normal, four mild assumptions have to be satisfied. They are: 1) The noise support spans a uniform and symmetrical support around zero; 2) The parameter support space contains the true realisation of the unknown parameters; 3) The noise terms are independently and identically distributed; 4) The design matrix is of full rank. Assumptions (3) and (4) cannot be easily enforced and sustained when the number of parameters exceeds the number of observations, or the number of observations is limited. In addition, when there are few data points, multicollinearity is increased by the small variation in the data. For statistical inference, GME/GCE approaches require the inversion of the cross-product matrix ***X’X***, which is often problematic when the number of linear dependencies is increased in the design matrix. Often, the design matrix is not of full rank. Under such circumstances, statistical inference is not helpful.

This thesis relied on principles from information theory for evaluating the information content of the parameter estimates, as well as of the NSI included during estimation. In this way it was possible to determine to what extent NSI departed from the initially used SI. However, information measures cannot be generally interpreted as a one-to-one substitute for the classical statistical tests.

Static versus dynamic modelling

In this thesis, both static models as well as models able to capture several dynamic elements were utilised. Chapters 2 and 3 were based entirely on a static approach, whereas chapters 4 and 5 were able to explicitly model dynamic elements. For countries under transformation with sudden political and institutional regime shifts, dynamic characteristics are likely to be important when analysing the evolution and equilibrium of the system under scrutiny. In chapter 4 the standard dual restricted profit function framework was complemented by stock adjustment equations for the quasi-fixed inputs (dairy cow stock and permanent pasture). The underlying assumption was that in the medium run, farmers are not able to fully adjust their quasi-fixed factors towards their desired levels. This assumption was also motivated by the finding from chapter 3, which showed a sluggish input adjustment to changed levels of outputs. As a consequence of this, the quasi-fixed inputs were modelled through a partial adjustment-like mechanism in which a correction was made for the quasi-fixed level attained, based on the lagged optimal levels and the lagged levels attained. In this way it was possible to capture medium-run dynamics in the quasi-fixed inputs. The typical herd inventory management of cattle does in itself induce particular dynamics which are discussed in Chavas and Johnson (1982), Rosen (1987), Schmitz (1997), and Jongeneel (2000). Medium-run dynamics were also captured for permanent pasture, which is likely as a consequence of the transition reform (i.e. privatisation and redistribution of agricultural land) to adjust to a new market equilibrium (particularly Hungary, see also chapter 2). Dynamic elements were also analysed when modelling the dairy farm structure of Hungary and Poland as following a first-order Markov chain process (Lee, Judge and Zellner (1970), Golan, Judge and Miller (1996), Lee and Judge (1996)). This approach using aggregate farm size data allowed the shifts/movements (dynamics) from the different farm-size breeding classes to be determined (see chapter 1 as well as chapter 5).

Stochastic frontier analysis

In the efficiency and productivity analysis literature two techniques are used to estimate/envelop a frontier. One is the so-called data envelopment analysis (DEA) (Charnes, Cooper and Rhodes (1978), Banker, Charnes and Cooper (1984)), the other is stochastic frontier analysis (SFA) (Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977)). For a more detailed overview of the two methodologies, see Murillo-Zamorano (2004) and Coelli, Prasada Rao, O'Donnell and Battese (2005). SFA approaches are well suited to handle agricultural applications, particularly when dealing with developing and transition economies, which are likely to be influenced by measurement error. In addition, given that agriculture is a biological activity in which random effects such as weather, disease, and inappropriate agricultural practices may have important influences on the correct placement of the frontier, it is important to rely on estimation techniques which explicitly model noise in the data[62]. Another reason supporting the choice of a SFA approach was related to the small number of observations available for computing productivity measures.

[62] The parameters of the stochastic production frontier models are usually estimated by maximum-likelihood methods based on an iterative maximisation procedure. The gamma parameterisation is often used, since it allows suitable starting values to be selected for the iterations (Battese and Corra (1977)). Since the seminal work by Banker and Maindiratta (1992) and Banker (1993), an increasing number of studies have extended DEA from the deterministic frontier to the stochastic frontier.

When the number of repeated observations over the same units is small, DEA scores are likely to be affected by the amount of output and input variables included in the model (Cubbin (2004)). In a DEA approach, when productivity indexes between adjacent years are being computed, comparisons are typically made enveloping contemporaneous[63] frontiers for each year. In order to increase the number of decision-making units and the robustness of the DEA scores, it is possible to envelop all the observations for the entire period, as such an intertemporal frontier is enveloped. Conversely, frontiers can also be estimated for a subset of observations, using a sequential framework which can be implemented through a window approach. However, Asmild, Paradi, Aggarwall and Schaffnit (2004) show that the standard decomposition in technical change and efficiency change usually made in computing Malmquist productivity indexes based on DEA window analysis scores provides spurious results which are highly unreliable.

The Malmquist index of total factor productivity

Several approaches for measuring total factor productivity (TFP) are available from the literature (Coelli, Prasada Rao, O'Donnell and Battese (2005: 85-131)). In chapter 2, TFP growth was recovered using a Malmquist Index (MI) (Caves, Christensen and Diewert (1982), Coelli, Prasada Rao, O'Donnell and Battese (2005)). First, the MI as compared to the more traditional Tornqvist/Fischer index numbers does not necessarily require the use of price information. Given the strong data limitation encountered, price information for transition economies is difficult to obtain and when available is frequently biased by inflation issues. Second, for countries undergoing transformation it may be somewhat too restrictive to assume that all units under observation are fully technically efficient, as is implicitly required by the Tornqvist/Fischer index numbers. Third, the use of an MI does not necessarily require the imposition of cost minimisation and revenue maximisation, which are required when computing Tornqvist/Fischer indexes. Finally, the MI explicitly takes into account the decomposition of TFP into efficiency change and technical change, which are important performance indicators. Technical efficiency is an attractive concept for measuring the performance of former socialist countries because it focuses solely on the maximum attainable output level for a given set of inputs without necessarily requiring strong neoclassical behavioural assumptions (Brada, King and Ma (1997)).

[63] For the conceptualisation of contemporaneous, intertemporal and sequential frontiers, see Charnes, Clark, Cooper and Golany (1985).

Time-varying inefficiency models

The estimation of an MI using stochastic frontier methods requires the specification of a time-varying inefficiency model which also incorporates technical change. Time-varying inefficiency models have been proposed in the literature by Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990), Battese and Coelli (1992), and Lee and Schmidt (1993). Cornwell, Schmidt and Sickles (1990) proposed a model with intercept parameters different for different units in different time periods. Lee and Schmidt (1993) specified the time-varying inefficiency effects as the product of individual units and time effects. Although the models of Cornwell, Schmidt and Sickles (1990) and Lee and Schmidt (1993) are more flexible than the models of Kumbhakar (1990) and Battese and Coelli (1992) they all require the estimation of additional parameters, which may complicate the estimation when only few pooled longitudinal time series are available. Another possibility was to use the Battese and Coelli (1995) model, which can measure TFP growth, allowing the different countries to exhibit technical efficiencies characterised by different levels and trend. However, by requiring the inclusion of country-specific dummy variables in specifying the technical inefficiency effects, this model too usually requires more observations than required by the earlier model of Battese and Coelli (1992)[64]. This is why in chapter 2 the latter model (Battese and Coelli (1992)) was used to estimate a stochastic frontier production function from which an MI of TFP growth was retrieved. One of the most important restrictions of the model was that the efficiencies of all units follow a common trend, although they are allowed to differ in levels. The required economic regularity conditions, which in the past were often not sufficiently verified in the SFA literature, were satisfied in this analysis (i.e. monotonicity and concavity)[65].

Distance function approach

Distance functions began be used more often in applied production economics in the last decade, although they were first introduced back in the 1970s by Shepard (1970). Their attractiveness derives from the ease in modelling multi-output technologies. The most popular solutions in modelling multi-output technologies were for a long time based on primal

[64] The more flexible specification of Battese and Coelli (1995) failed to provide unambiguous estimates because of problems in converging to optimal solutions.
[65] Note that Bayesian approaches are now available to estimate SFA model. Bayesian methods allow for the direct imposition of regularity conditions.

approaches aggregating outputs into a single index of output or relying on dual representations of the production technology (i.e. cost or profit functions). The distance function enables a primal alternative in modelling multi-output technologies without requiring aggregation, prices and strong behavioural assumptions which may be difficult to ensure for countries undergoing transformation. Distance function approaches have been applied in particular for efficiency and productivity analysis (Coelli and Perelman (1996), Bjorndal, Koundouri and Pascoe (2002), Brümmer, Glauben and Thijssen (2002), Morrison-Paul, Johnston and Frengley (2002a, 2002b), among others). Brümmer, Glauben and Thijssen (2002) used a distance function approach to decompose the source of productivity growth for an unbalanced panel of 700 farms from 1991 to 1994 for the region around Poznan in Poland.

Coelli (2002) showed that the suspicion that regressor endogeneity may introduce potential simultaneous equations bias can easily be allayed. As such the distance function is able to provide consistent estimates under a set of specific behavioural assumptions. In chapter 3, use was made of an output distance function framework in solving a problem characterised by "negative" degrees of freedom. In order to add information to the system under scrutiny, additional information was introduced through constraints in the estimation. One of the sources of NSI came from imposing a mild revenue maximisation condition from the duality theory of the output distance function. The distance function framework also enabled the exploitation of other restrictions in terms of constraints (i.e. elasticity sign/magnitude, input homogeneity/monotonicity). In addition, for the first time in this thesis, several stochastic equality restrictions were elaborated and added to the estimation procedure as constraints which helped in formulating the constraints introduced in chapter 4.

In using a distance function in chapter 3, the analysis done in chapter 2 was further complemented by augmenting technical efficiency measures with several indicators about allocative inefficiencies. In chapter 2, an SFA approach was used to estimate country-level technical efficiencies representing a country's ability to obtain the maximum output from a given set of inputs. On the other hand, the focus in chapter 3 through a distance function approach was on estimating country-level allocative inefficiencies which express a country's ability to produce the output in optimal proportions, given the price and production technology prevailing in the country in question.

The Markov problem

For many years, a focus of applied research was the analysis of farm structure in agricultural economics (Judge and Swanson (1962), Gillespie and Fulton (2001), Karantininis (2002), among others). Some of the most recurrent research questions addressed in the literature are: which farms are likely to survive? which are likely to exit from the sector? what determines the farm size distribution? what will be the farm size distribution? These research questions were usually addressed by relying on simple growth models, either stochastic or deterministic (Lucas (1978), Jovanovic (1982), among others), that could be deduced from the Gibrat's law, which states that farm growth is independent of farm size. When for estimation purposes a linear regression representation of the Gibrat's law is used, there are several problems, as indicated by Kostov, Patton, Moss and McErlean (2005). One problem is connected to the assumed linear effects of the additional explanatory variables which are selected in explaining farm growth. The literature search revealed significant non-linearities in explaining farm growth (Weiss (1999)). A second problem is that the simple models testing for the Gibrat's law usually assume that the law holds (or is violated) globally across all farms. In this way it is not possible to discriminate if the Gibrat's law holds (or is violated) among different farm size groups. In addition, stochastic growth models typically require micro farm data, which were not available for this research.

An alternative to growth models, which can be used even when only aggregated data of finite size categories are available, is the so-called Markov chain approach (Lee, Judge and Zellner (1970), Golan, Judge and Miller (1996), Lee and Judge (1996)). The Markov chain approach recasts the problem such that transition probabilities are used to model the underlying farm dynamics between different farm size categories. Through the inclusion of an inactive farm class it was possible to determine which farms were likely to exit from the sector and at the same time also which farms were likely to remain in business. The instrumental variable approach used for Poland allowed to determine non-stationary effects explaining the Markov transition probability matrix (Golan and Vogel (2000), Courchane, Golan and Nickerson (2000)). In addition, given that instrumental variable techniques provide a consistent estimator in a situation in which a regressor is contemporaneously correlated with the error, it helped in dealing with potential errors in variables Kennedy (2003: 159).

6.3 Synthesis of results

This section provides a conclusive synthesis of results. Table 6.2 summarises the analyses done in the different chapters by relating the research questions to the findings of this thesis. Chapters 2 and 3 dealt with the agriculture of several CEECs undergoing transformation. In chapter 2 it was shown that sole reliance on partial productivity indicators may lead to misleading conclusions on the country performances. In addition, support was found for the proposition that countries characterised by large-scale farming perform better than countries with small-scale farming. When carrying out that analysis, use was made of panel data for Bulgaria, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia for the period 1993–2002. In the first part of chapter 2, partial productivity indicators were derived and discussed; in the second part, an MI of TFP growth was econometrically estimated, relying on a stochastic frontier approach. In the first part, the main causes of the output decline in agriculture were discussed in relation to several economic indicators. Then the privatisation process for land and non-land assets and the farm structure was discussed.

The Baltic States plus Slovakia were the countries which experienced the greatest contraction in terms of agricultural output after transition. This was due to the negative effect of the transition reform on relatively capital-intensive agriculture (i.e. livestock farming). In this transforming environment, the need to assess the agricultural productivity performance of the CEECs after reform was a challenging task. The estimated production frontier model returned production elasticities that were comparable to those found in previous studies in the literature (see Table 2.6 in chapter 2).

The TFP growth estimates for the ten CEECs considered in the analysis were positive, although given the sharp decline in output observed after transition it would have not been surprising to find negative growth rates. This indicates that regardless of the political and institutional break caused by transition, agricultural performance on an aggregate level nevertheless developed positively. Productivity growth was found to be entirely driven by technological change, whereas efficiency declined slightly over time. Although the decline in efficiency after reform might seem counterintuitive, it could be explained by the sluggish adaptation of the input mix to the newly established output level after reform[66].

[66] The adaptation of the input mix after transition was explicitly taken into account in chapter 4, where quasi-fixed inputs were modelled following a partial adjustment mechanism.

Table 6.2 Synthesis of results, by chapters

Chapter	Research questions	Approach	Estimation	Conclusions in brief
2	• Is the collapse of agricultural output a good indicator of economic performance for the ten CEECs which applied in 1998 for EU accession?	Stochastic Production Frontier	Maximum Likelihood	• Sole reliance on the decline of agricultural output is not a sufficient indicator for measuring the overall agricultural performance
	• Do countries with large-scale farming perform better than countries with small-scale farming?			• Large-scale farming performs better than small-scale farming during periods of uncertain economic conditions
3	• How do the transition-induced adjustments to the mix of agricultural outputs differ between Hungary and Poland?	Distance Function Approach	Generalised Maximum Entropy	• After reform most agricultural outputs declined • It is going to be difficult to increase chicken meat getting rid of the other agricultural products on the PPC • Allocative inefficiencies in the output mix were greater in Hungary than in Poland • Overspecialization was found for sugar beets both in Hungary and Poland

Source: Author’s presentation.

Table 6.2 Synthesis of results, by chapters (continuation from previous page)

Chapter	Research questions	Approach	Estimation	Conclusions in brief
4	•How is it possible to model the post-socialist dairy supply for Hungary and Poland in the face of severe data limitations and institutional hiatuses?	Profit Function	Generalised Maximum Entropy	• An estimation procedure which reconciles SI and NSI is elaborated by exploiting primal and dual relationships as constraints during the estimation
	•Are the calibrated elasticities used in the dairy partial equilibrium models found in the literature empirically acceptable?			• It is empirically proven that the calibrated elasticities used in the literature are not far from reality
5	•How has the dairy farm structure of Hungary and Poland changed in the post- socialist period?	First Order Markov Chain	Generalised Cross Entropy	• Dairy farms will continue to decline in Hungary and Poland in the coming decade ,with an increase in the number of medium and large dairy farms
	•Which dairy farms are likely to survive in the future?			• In the future, the dairy farm structures of Hungary and Poland are likely to converge to a European farming style

In terms of the ranking, the estimated TFP growth disaggregated at country level was similar to that found in other studies (see chapter 2), supporting Slovenia as the best performing country and Latvia as the worst performing country over the period considered.

Technical efficiency could also be estimated from the estimated stochastic production frontier. The estimated technical efficiency scores showed that, with the exception of Hungary which showed a level of technical efficiency equal to 0.96, the remaining CEECs were on average quite far from the best-practice frontier, indicating that those countries were using a suboptimal input mix. Estimates supported the view that countries that did not demolish their large-scale farming structure tended to be more technically efficient than those following policies for small-scale farming.

In chapter 3, use was made of a multi-output distance function complemented by several theoretical constraints during estimation. The empirical focus was in analysing to what extent the adjustment in agricultural output mix after reform differed across Hungary and Poland. In addition, chapter 3 measured the extent of allocative inefficiencies in adapting the agricultural output mix to changes in prices and recovering some stereotypical facts.

Several production statistics were econometrically derived for two sub-samples: one for the period 1991–1995 and the other for the period 1996–2001. The arbitrary choice to determine sub-samples for analysis was justified by the typical U-shaped curve encountered in the literature, with a fall in output in the first half of the 1990s and a recovery in the second half of the 1990s (Blanchard (1998: 1-24)). Post-reform in the first half of the 1990s, the majority of agricultural outputs declined, especially milk and beef and veal production. Output prices showed large growth rates in the last decade with the only exception made for potatoes, which had also a declining trend in terms of quantity.

From looking at the estimated output elasticities based on distance function it appeared that over the sample under scrutiny, for both Hungary and Poland the greatest productive contribution came from milk/beef/veal output. However, this contribution was lower for the 1991–1995 periods as compared to the 1996–2001 period. The findings were similar for chicken meat and sugar beet. The increase in the productive contribution of chicken meat on production can be attributed to two factors. First, post reform, chicken meat constituted a valid alternative to beef/veal meat in a period where the consumer purchasing power for food products was particularly low. Second, the increase in chicken meat represented a shift in consumer preference towards low-fat white meats. However the detected difficulty in moving a long the PPC increasing chicken to the detriment of other output may result more difficult in the future.

Adjustment costs were greater and increasing over time for Hungary as compared to Poland. This could be partly explained by the relatively high and increasing level of producer support in Hungary which may have introduced market distortions as compared to Poland. Adjustment costs were relevant particularly for sugar beets indicating overspecialization for sugar beet. Conversely the shadow valuation of chicken meat was in line with market valuation. However this situation may change if further increases on chicken meat production will not be justified by price increases. Second order substitutability measures indicated an increasing degree of complementarity and substitutability in the second half of the 1990s with respect to the period immediately following reform.

In chapter 4, an innovative empirical framework in modelling the dairy and beef supplies was developed for Hungary and Poland. A comparison of the different model results clearly showed that without the contemporaneous enforcement of theoretical restrictions and NSI, the model would have provided spurious results. As such, for countries undergoing transformation, the use of NSI is extremely important for sound empirical model estimates.

For both countries there appeared to be a positive trend for the milk supplies and a negative trend for beef. This could be partly attributed to the gradual specialisation of the dairy cow stock towards dairy production. The addition of the demand for the quasi-fixed inputs showed that the quasi-fixed inputs depended predominantly on the lagged levels achieved. Therefore the investment decision should only partly be based on the level of the other quasi-fixed inputs and dairy and beef output price levels. This at least for livestock can be supported by the rather limited market for heifers and even for dairy cows. Any trade in these animals is farm to farm, based on personal contacts.

The supply elasticities for dairy and beef were both inelastic in the short as well as in the medium run. Final estimates were not so different from those found for EU-15 countries in the pre-quota period. For Hungary and Poland medium-run dairy supply estimates were 0.26 and 0.25 respectively. This confirms the expectation that although the dairy and beef farm structures differ across countries, dairy operations rely on a similar production technology (Jongeneel (2000: 175)). Bezlepkina, Oude Lansink and Oskam (2005) found a milk supply elasticity for Russia in the post-transition period which did not differ from the one found for EU-15 countries. The empirical dairy supply elasticities which were estimated showed that the calibrated elasticities used in the dairy partial equilibrium models encountered in the literature are not far from reality (see Table 4.1). Of course, the final estimates in chapter 4 were influenced by the choice made in the NSI introduced during the estimation, which was partly based on previous economic analysis for EU-15 countries. However, the entropy criterion had to comply at the same time with the moment consistency constraints represented by the sample data so that the final estimates were the result of both SI and NSI. In addition, the uncertainty attached to each restriction could in principle allow large deviations around their expected values, allowing the NSI to be ruled out by the sample data. The final model (Model 3) showed an acceptable within-sample predictive power for the four estimated equations as a system.

In chapter 5, the analysis focused on how the dairy farm structure of Hungary and Poland has changed during the post-socialist period, relying on a GCE approach (Golan, Judge and Miller (1996), Mittelhammer, Judge and Miller (2000)). In this way, further empirical information was provided to augment the introductory descriptive analyses done in chapter 2. Attention was given to modelling the dynamics of the dairy farm structure and to making projections for the coming decade on the likely dairy farm size configuration. The projections made for the dairy farm size structure of Hungary and Poland showed that the number of dairy farms is expected to decline inexorably in the coming decades, although the number of medium and large farms is expected to increase. More precisely: in Hungary, dairy farms with 30–99 dairy cows are expected to increase, whereas in Poland, farms with more than 30 dairy cows are expected to increase. This seems to be consistent with the historical development of farm structure in those countries. For Hungary, the restructuring and modernisation of the former large collective structures is expected to gradually adjust into smaller but more viable farm units. On the other hand for Poland, the average dairy farm size is expected to grow slightly, through a process of consolidation/concentration. Subsistence farms producing cow’s milk are expected to leave the sector in the next seven years in Hungary and the next fifteen years in Poland. This is likely to proceed more slowly in Poland than in Hungary, since Hungary is facing a more drastic restructuring. These findings confirmed that in the near future the dairy farm size configuration of Hungary and Poland is likely to converge to that in Europe. The outcome will depend on the extent to which the land market will be able to function properly in allocating land to the most efficient farmers. The economic environment will probably affect the process, since without robust economic conditions it is not possible to absorb the unskilled labour force in the industrial and service sectors.

6.4 Some suggestions for further research

In this section, points for further research are briefly discussed. These aspects are arguments that could not be directly examined in the thesis because not initially planned or because it was not possible to answer them efficiently within the available time. Below, the research outlooks have been elaborated; they may help generate new research questions, new methodological approaches, and new policy issues.

Given the so-called U-shaped output curve for many transition economies after the 1990s, it could be interesting to explore different time-varying inefficiency models on the basis of chapter 2. One possibility would be to specify a model which is able to capture differences in levels as well as in trends for the two sub-periods 1991–1995 and 1996–2001. Another possibility would be to model time as a quadratic function in the currently estimated model, in order to gain more flexibility. An additional research topic would be to assess the contribution of the pre-accession programmes on productivity growth and the decomposition of such growth into efficiency change and technological change.

In chapter 3, if price information become available for the input set, it would be possible to exploit similar prior information as done for the output set. The model would gain more flexibility by allowing the input second order terms of the transcendental logarithmic specification to be estimated. This would increase the flexibility of the estimated model.

One of the limitations of chapter 4 was on focusing on modelling the commercial milk supply of Poland and Hungary. However in Poland a considerable amount of milk production comes from subsistence farming. Therefore an extension could be to specifically model the milk supply coming from subsistence farming and test to what extent the price responsiveness differ to the response characterizing commercial milk.

An alternative technique to GCE approach is the Bayesian first order Markov state model, which can also handle the incorporation of prior information on transition probabilities. This would help as a supplementary approach in testing the robustness of the final estimates obtained.

6.5 Principal conclusions

This section is a shorter and more focused version of section 6.3. The thesis set out to answer several research questions, which were motivated and set out in chapter 1. All the research questions were addressed by using a variety of methods drawn largely from the economics of production and econometrics. In spite of the diversity in the questions addressed and in the methodologies that were followed, this section attempts to summarise the main conclusions.

1. Despite the decrease in output, TFP growth rates were positive across all ten CEECs analysed in this thesis. Given the sudden decrease in agricultural output and the well-known immobility of production factors in agriculture, it would not have been surprising to find negative TFP growth. This suggests that the decline in agricultural output is not a sufficient indicator for measuring the overall agricultural performance. So an analysis focusing solely on this aspect provides a partial and misleading interpretation of the consequences of agricultural reform.
2. Countries such as Bulgaria, Czech Republic, Hungary, and Slovakia, which during the socialist regime were characterised by large-scale operators, were more technologically efficient compared with the other countries analysed. Technical efficiency scores were low in countries where small individual family farms predominated. This is in agreement with the view that large-scale farming performs better than small-scale farming for situations with missing markets and uncertain economic conditions.
3. After transition, the agricultural output mix was negatively influenced. On the one hand, dairy production decreased, whereas on the other, chicken meat increased. However it is going to be difficult to move to chicken on the PPC getting rid of other outputs. Allocative inefficiencies in the output mix composition were greater in Hungary than in Poland. This could be explained by the agricultural support level, which was stronger in Hungary than in Poland, and may have induced market distortions. Overspecialization was found for sugar beet. The second half of the 1990s was characterized by an increased degree of complementarity and substitutability suggesting that immediately after reform these relationships were "frozen".
4. The importance of using NSI to solve an "ill-posed" and "ill-conditioned" problem was demonstrated in chapter 4. An alternative was presented to the more simple calibration exercises. Most of the partial equilibrium models encountered in the literature are based solely on assumed or guessed parameter estimates which are not sufficient to capture the specificities of CEECs. For example for countries under transformation it is relevant to capture dynamic adjustments such as how the dairy cow stock is going to adjust in the medium run. A rigorous and transparent procedure was developed to combine information from primal and dual perspectives. The results showed dairy and beef

inelastic own price responses for Hungary and Poland. Complementarity was found between the production of milk and beef in the medium run.

5. The estimates coming from the econometric model elaborated in chapter 4 were also helpful in validating the calibrated elasticities used in the currently available partial equilibrium models focusing on dairy. Focusing on the estimated medium run milk supply elasticities estimates it was found that they were on average close to the calibrated elasticities used in partial equilibrium. This proved that the calibrated elasticities used in the literature are not far from reality.
6. The number of dairy farms in Hungary and Poland will continue to decline in the coming decade, although with an increase in the number of medium and large farms. For Hungary, the ongoing restructuring of the former large-scale collective farms is likely to continue, with the largest units being dismantled into medium-sized viable units. On the other hand, in Poland a consolidation process is expected, where small dairy farms (i.e. subsistence farms) are expected to leave the sector gradually[67]. The exodus of the subsistence dairy farms is predicted to proceed more slowly in Poland than in Hungary, with the latter country facing more drastic restructuring.
7. The findings on the evolution of the dairy farm structure of Hungary and Poland confirm that in the near future the dairy farm structure is likely to converge to a European dairy farming style. The concentration of land in fewer but more efficient farms depends on the mediating role of a well-defined and functioning land market. The lack of such a market not only hampers efficient land allocation, but also limits access to capital (land credit, mortgage) and hence investments.

[67] Sznajder (2002), states that an optimal viable farm size for Poland requires about 20–25 dairy cows.

References

ABELE, S., and K. FROHBERG (2003): *Subsistence Agriculture in Central and Eastern Europe: How to Break the Vicious Circle?* Halle (Saale): Institute of Agricultural Development in Central and Eastern Europe (IAMO).

ADELMAN, I. G. (1958): "A Stochastic Analysis of the Size Distribution of Firms," *Journal of the American Statistical Association*, 53, 893-904.

AGRAEUROPE (2000): "Milk Production to Post Further Decline in 2000," *AgraFood East Europe*, April, 18-19.

AIGNER, D. J., C. A. K. LOVELL, and P. J. SCHMIDT (1977): "Formulation and Estimation of Stochastic Frontier Production Function Models," *Journal of Econometrics*, 6, 21-37.

ALTMAN, M. (2004): "Statistical Significance, Path Dependency, and the Culture of Journal Publication," *The Journal of Socio-Economics*, 33, 651-663.

ASMILD, M., J. C. PARADI, V. AGGARWALL, and C. SCHAFFNIT (2004): "Combining DEA Window Analysis with the Malmquist Index Approach in a Study of the Canadian Banking Industry," *Journal of Productivity Analysis*, 21, 67-89.

BANKER, R. D. (1993): "Maximum Likelihood, Consistency and Data Envelopment Analysis: A Statistical Foundation," *Management Science*, 39, 1265-1273.

BANKER, R. D., A. CHARNES, and W. W. COOPER (1984): "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis," *Management Science*, 30, 1078-1092.

BANKER, R. D., and A. MAINDIRATTA (1992): "Maximum Likelihood Estimation of Monotone and Concave Production Frontiers," *Journal of Productivity Analysis*, 3, 401-415.

BANSE, M., and H. GRETHE (2005): How Will Decreasing Subsistence Production Affect Future Dairy Markets in the Central European Countries? Proceedings of the 89th European Association of Agricultural Economists (EAAE) "Modelling Agricultural Policies: State of the Art and New Challenges" ed. by F. Arfini. Parma: Monte Universitá Parma, 863-882.

BATTESE, G. E., and T. J. COELLI (1992): "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India," *Journal of Productivity Analysis*, 3, 153-169.

— (1995): "A Model for Technical Inefficiency Effects in a Stochastic Production Function for Panel Data," *Empirical Economics*, 20, 325-352.

BATTESE, G. E., and G. S. CORRA (1977): "Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia," *Australian Journal of Agricultural Economics*, 21, 169-179.

BEATTIE, B. R., and C. R. TAYLOR (1985): *The Economics of Production*. Malabar, Florida: Krieger Publishing Company.

BELSLEY, D. (1991): *Conditioning Diagnostic: Collinearity and Weak Data in Regression*. New York: John Wiley and Sons.

BEZLEPKINA, I. (2004): "Microeconomic Analysis of Russian Agricultural Enterprises," PhD Dissertation, Wageningen: Wageningen University, 1-184.

BEZLEPKINA, I. V., A. G. J. M. OUDE LANSINK, and A. J. OSKAM (2005): "Effects of Subsidies in Russian Dairy Farming," *Agricultural Economics*, 33, 277-288.

BJORNDAL, T., P. KOUNDOURI, and S. PASCOE (2002): "Multi-Output Distance Function for the North Sea Beam Trawl Fishery," London, CSERGE, Department of Economics, University College London.

BLACKORBY, C., and R. R. RUSSELL (1989): "Will the Real Elasticity of Substitution Please Stand Up? (A Comparison of the Allen/Uzawa and Morishima Elasticities)," *The American Economic Review*, 79, 882-888.

BLANCHARD, O. (1998): *The Economics of Post-Communist Transition*. Oxford: Claredon Press.

BLANGIEWICZ, M., T. D. BOLT, and W. W. CHAREMZA (1993): "Alternative Data for the Dynamic Modelling of the Eastern European Transformation," *Journal of Economic and Social Measurement*, 20, 1-23.

BOOTS, M., A. G. J. M. OUDE LANSINK, and J. PEERLINGS (1997): "Efficiency Loss Due to Distortions in Dutch Milk Quota Trade," *European Review of Agricultural Economics*, 24, 31-46.

BOSTWICK, D. (1962): "Yield Probabilities as a Markov Process," *Agricultural Economics Research*, 14, 49-56.

BRADA, J. C. (1989): "Technological Progress and Factor Utilization in Eastern European Economic Growth," *Economica*, 56, 433-48.

— (1996): "Privatization Is Transition - or Is It?," *Journal of Economic Perspectives*, 10, 67-86.

BRADA, J. C., and A. E. KING (1993): "Is Private Farming More Efficient Than Socialized Agriculture?," *Economica*, 60, 41-56.

BRADA, J. C., A. E. KING, and C. Y. MA (1997): "Industrial Economics of the Transition: Determinants of Enterprises Efficiency in Czechoslovakia and Hungary," *Oxford Economic Papers*, 49, 104-127.

BROOKE, A., D. KENDRICK, A. MEERAUS, R. RAMAN, and R. E. ROSENTHAL (1988): *GAMS: A User's Guide*. South San Francisco: The Scientific Press.

BRÜMMER, B., T. GLAUBEN, and G. THIJSSEN (2002): "Decomposition of Productivity Growth Using Distance Functions: The Case of Dairy Farms in Three European Countries," *American Journal of Agricultural Economics*, 84, 628-644.

BURRELL, A. (1992): "The Effect of EC Milk Quota's on the Milk and Livestock Sectors in the UK," *Oxford Agrarian Studies*, 20, 19-37.

BURRELL, A. (2000): "The Future of Dairy Policy in the European Union," *Advances in Dairy Technology*, 12, 313-322.

CARLIER, J. P. (2000): "Le Secteur Laitier Hongrois á la Veille des Négociations d'Adhésion avec l'Union Européenne," Paris: Association de la Transformation Laitière Française (ATLA), 1-31.

CARTER, C. A., and B. ZHANG (1994): "Agricultural Efficiency Gains in Centrally Planned Economies," *Journal of Comparative Economics*, 18, 314-328.

CAVES, D. W., L. R. CHRISTENSEN, and W. E. DIEWERT (1982): "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity," *Econometrica*, 50, 1393-1414.

CHAMBERS, R. G. (1988): *Applied Production Analysis a Dual Approach*. Cambridge, New York: Cambridge University Press.

CHARNES, A., C. T. CLARK, W. W. COOPER, and B. GOLANY (1985): "A Developmental Study of Data Envelopment Analysis in Measuring the Efficiency of Maintenance Units in the U.S. Air Forces," *Annals of Operation Research*, 2, 95-112.

CHARNES, A., W. W. COOPER, and E. RHODES (1978): "Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, 2, 429-444.

CHAVAS, J.-P., and S. R. JOHNSON (1982): "Supply Dynamics: The Case of U.S. Broilers and Turkeys," *American Journal of Agricultural Economics*, 64, 558-564.

CHIANG, A. C. (1984): *Fundamental Methods of Mathematical Economics*. New York: McGraw-Hill, Inc.

COELLI, T. (2002): "On the Econometric Estimation of the Distance Function Representation of a Production Technology," Louvain: Centre for Operations Research and Economics Series Papers 0042, Catholique de Louvain.

COELLI, T., and S. PERELMAN (1996): "Efficiency Measurement, Multiple-Output Technologies and Distance Functions: With Application to European Railways," Liege: Centre de Recherche en Economie Publique et de la Population (CREPP) Discussion Paper no. 96/05.

— (2000): "Technical Efficiency of European Railways: A Distance Function Approach," *Applied Economics*, 32, 1967-1976.

COELLI, T., D. S. PRASADA RAO, and G. E. BATTESE (1998): *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

COELLI, T., D. S. PRASADA RAO, C. J. O'DONNELL, and G. E. BATTESE (2005): *An Introduction to Efficiency and Productivity Analysis*. New York: Springer.

COELLI, T., S. RAHMAN, and C. THIRTLE (2003): "A Stochastic Frontier Approach to Total Factor Productivity Measurement in Bangladesh Crop Agriculture, 1961-92," *Journal of International Development*, 15, 321-333.

COELLI, T. J., and D. S. PRASADA RAO (2003): "Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000," Durban: Conference of the International Association of Agricultural Economics (IAAE).

COLMAN, D., A. SOLOMON, and L. GILL (2005): "Supply Response of U.K. Milk Producers," *Agricultural Economics*, 32, 239-251.

COLOMBATTO, E. (2002): "Is There an Austrian Approach to Transition?," *The Review of Austrian Economics*, 15, 61-74.

CONWAY, R. K., and R. C. MITTELHAMMER (1986): "The Theory of Mixed Estimation in Econometric Modeling," *Studies in Economic Analysis*, 10, 79-120.

CORBO, V., and P. MELLER (1979): "The Translog Production Function: Some Evidences from Establishment Data," *Journal of Econometrics*, 1, 193-199.

CORNWELL, C., P. SCHMIDT, and R. C. SICKLES (1990): "Production Frontiers with Cross-Sectional and Time Series Variation in Efficiency Levels," *Journal of Econometrics*, 46, 185-200.

COURCHANE, M., A. GOLAN, and D. NICKERSON (2000): "Estimation and Evaluation of Loan Discrimination: An Informational Approach," *Journal of Housing Research*, 11, 67-90.

CSAKI, C., and Z. LERMAN (2002): "Land and Farm Structure in Transition: The Case of Poland," *Eurasian Geography and Economics*, 43, 305-322.

CSAKI, C., and J. NASH (1998): "The Agrarian Economies of Central Eastern Europe and Commonwealth Independent States: Situation and Perspectives, 1997," Washington DC: World Bank Discussion Paper 387.

CUBBIN, J. (2004): "Some More Statistical Properties of Data Envelopment Analysis," London: Economic Department, City University.

CZYZEWSKI, A. B., W. M. ORLOWSKI, L. ZIENKOWSKI, Z. ZOLKIEWSKI, and W. GUBA (2000): "Polish Agriculture: Economic Transition and Long Run Trends " in *Perspectives on Agriculture in Transition: Analytical Issues, Modelling Approaches, and Case Study Results*, ed. by W.-R. Poganietz, A. Zezza, K. Frohberg, and K. G. Stamoulis. Kiel Leibniz: Wissenschaftsverlag Vauk, 140-199.

DIEWERT, W. E. (1974): "Applications of Duality Theory," in *Frontier of Quantitative Economics*, ed. by M. D. Intrilligator, and D. A. Kendrick. Amsterdam: North Holland Press., 106-171.

DIEWERT, W. E., and T. J. WALES (1987): "Flexible Functional Forms and Global Curvature Conditions," *Econometrica*, 55, 43-68.

DISNEY, W. T., P. A. DUFFY, and W. E. HARDY JR (1988): "A Markov Chain Analysis of Pork Farm Size Distributions in the South," *Southern Journal of Agricultural Economics*, 20, 57-64.

DRIES, L., and J. SWINNEN (2004): "Foreign Direct Investment, Vertical Integration, and Local Suppliers: Evidence from the Polish Dairy Sector," *World Development*, 32, 1525-1544.

DUPUIS, M. (1993): "Subnational State Institutions and the Organization of Agricultural Resource Use: The Case of the Dairy Industry," *Rural Sociology*, 58, 440-60.

DURBIN, J. (1953): "A Note on Regression When There Is Extraneous Information About One of the Coefficients " *Journal of the American Statistical Association*, 48, 799-808.

ELHORST, J. P. (1990): "De Inkomensvorming En De Inkomensverdeling in De Nederlandse Landbouw Verklaard Vanuit De Huishoudproduktie Theorie," The Hague.

EC (1998): "Agricultural Situation and Prospects in the Central European Countries, Poland," Brussels: Directorate General for Agriculture (DG VI), European Commission (EC), 1-135.

— (2002): "Agricultural Situation in the Candidate Countries, Country Reports," Brussels: Directorate General for Agriculture (DG VI), European Commission (EC), 1-36.

— (2002a): "Agricultural Situation in the Candidate Countries, Country Report on Hungary," Brussels: Directorate General for Agriculture (DG VI), European Commission (EC), 1-36.

— (2002b): "Agricultural Situation in the Candidate Countries, Country Report on Poland," Brussels: Directorate General for Agriculture (DG VI), European Commission (EC), 1-36.

EUROSTAT (2005): "Tables: Structural Indicators, Employment," Luxembourg: Eurostat, European Commission (EC). (http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=STRIND_EMPLOI&root=STRIND_EMPLOI/emploi/em071, accessed: 28 November 2005).

— (2006a): "Database on Agriculture: Holdings with Dairy Cows by Number of Dairy Cows and Agricultural Area Size Classes," Luxembourg: Eurostat, European Commission (EC). (http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/agri/eurofarm/ef_2000/ef2_ls/ef2_graz&language=en&product=EU_MASTER_agriculture&root=EU_MASTER_agriculture&scrollto=0, accessed: 1 March 2006).

— (2006b): "Database on Agriculture: Price Indexes. Agricultural Input and Output Prices," Luxembourg: Eurostat, European Commission (EC). (http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/agri/prag/prixind/base_00&language=en&product=EU_MASTER_agriculture&root=EU_MASTER_agriculture&scrollto=0, accessed: 1 March 2006).

FAO (2004): "Faostat-Agriculture," Rome: Food and Agriculture Organization of the United Nations. (http://www.fao.org/waicent/portal/statistics_en.asp, accessed: 1 June 2004)

— (2005): "Faostat-Agriculture," Rome: Food and Agriculture Organization of the United Nations. (http://www.fao.org/waicent/portal/statistics_en.asp, accessed: 1 July 2005)

— (2006): "Faostat-Agriculture," Rome: Food and Agriculture Organization of the United Nations. (http://www.fao.org/waicent/portal/statistics_en.asp, accessed: 1 April 2006)

FAPRI (2004): "Fapri International Dairy Model," Ames: Food and Agricultural Policy Research Institute.

FÄRE, R. (1988): *Fundamentals of Production Theory*. Berlin: Springer-Verlag.

FÄRE, R., S. GROSSKOPF, M. NORRIS, and Z. ZHANG (1994): "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries," *The American Economic Review*, 84, 66-83.

FÄRE, R., and D. PRIMONT (1995): *Multi-Output Production and Duality: Theory and Applications*. Boston [etc.]: Kluwer Academic Publishers.

FISCHER BOEL, M. (2006): "The Future Framework of Milk Production in the EU," Viborg: European Dairy Farmers Congress.

FOMBY, T. B., and R. CARTER HILL (1997): *Applying Maximum Entropy to Econometric Problems* Greenwich: JAI Press Inc.

FRASER, I. (2000): "An Application of Maximum Entropy Estimation: The Demand for Meat in the United Kingdom," *Applied Economics*, 32, 45-59.

FRIES, R., and A. RUVINSKY (1999): *The Genetics of Cattle*. Wallingford: CABI Publishing.

FULGINITI, L. E., and R. K. PERRIN (1997): "LDC Agriculture: Nonparametric Malmquist Productivity Index," *Journal of Development Economics*, 53, 373-390.

GEARY, R. C. (1958): "A Note on the Comparison of Exchange Rates and Purchasing Power Parities between Countries," *Journal of the Royal Statistical Society*, 121, 97-99.

GEWEKE, J. K. (2005): *Contemporary Bayesian Econometrics and Statistics*. Hoboken: Wiley-Interscience.

GILLESPIE, J. M., and J. R. FULTON (2001): "A Markov Analysis of the Size of Hog Production Firms in the United States," *Agribusiness*, 17, 557-570.

GODDARD, E., A. WEERSINK, K. CHEN, and C. G. TURVEY (1993): "Economics of Structural Change in Agriculture," *Canadian Journal of Agricultural Economics*, 41, 475-489.

GOLAN, A. (2003): "An Information Theoretic Approach for Estimating Nonlinear Dynamic Models," *Studies in Nonlinear Dynamics & Econometrics*, 7, 1-24.

GOLAN, A., G. JUDGE, and D. MILLER (1996): *Maximum Entropy Econometrics: Robust Estimation with Limited Data*. Chichester: John Wiley & Sons.

GOLAN, A., G. G. JUDGE, and J. M. PERLOFF (1997): "Estimation and Inference with Censored and Ordered Multinomial Response Data," *Journal of Econometrics*, 79, 23-51.

GOLAN, A., J. M. PERLOFF, and E. Z. SHEN (2001): "Estimating a Demand System with Nonnegativity Constraints: Mexican Meat Demand," *Review of Economics and Statistics*, 83, 541-50.

GOLAN, A., and S. J. VOGEL (2000): "Estimation of Non-Stationary Social Accounting Matrix Coefficients with Supply-Side Information," *Economic Systems Research* 12, 447-471.

GOOD, I. J. (1963): "Maximum Entropy for Hypothesis Formulation, Especially for Multidimensional Contingency Tables," *Annals of Mathematical Statistics*, 34, 911-34.

GOW, H. R., and J. SWINNEN (1998): "Agribusiness Restructuring, Foreign Direct Invetsment, and Hold-up Problems in Agricultural Transition," *European Review of Agricultural Economics*, 25, 331-350.

GREENE, W. H. (2000): *Econometric Analysis*. Upper Saddle River: Prentice Hall.

GRETHE, H., and G. WEBER (2005): Comparing Supply Systems Derived from a Symmetric Generalized Mcfadden Profit Function to Isoelastic Supply Systems: Costs and Benefits, Proceedings of the 89th European Association of Agricultural Economists (EAAE) "Modelling Agricultural Policies: State of the Art and New Challenges" ed. by F. Arfini. Parma: Monte Universitá Parma, 98-116.

GRIFELL-TATJÉ, E., and C. A. K. LOVELL (1995): "A Note on the Malmquist Productivity Index," *Economics Letters*, 47, 169-175.

GRIFFITHS, W. E., R. C. HILL, and G. G. JUDGE (1993): *Learning and Practicing Econometrics*. New York: John Wiley & Sons, Inc.

GRILICHES, Z. (1986): "Economic Data Issues," in *Handbook of Econometrics*, ed. by Z. Griliches, and M. D. Intrilligator. Amsterdam: North-Holland Publishing Company, 1466-2107.

GROSSKOPF, S., K. HAYES, and J. HIRSCHBERG (1995): "Fiscal Stress and the Production of Public Safety: A Distance Function Approach," *Journal of Public Economics*, 57, 277-296.

GROSSKOPF, S., D. MARGARITIS, and V. VALDMANIS (1995): "Estimating Output Substitutability of Hospital Services: A Distance Function Approach," *European Journal of Operational Research*, 80, 575-587.

HALLAM, D. (1998): "Analysing Agricultural Supply Response in Economies in Transition," in *Agricultural Price Reform under Transition in Bulgaria, Romania, and Slovenia*, ed. by G. Mergos. Chania: International Centre for Advanced Mediterranean Agronomic Studies, 123-131.

HAYAMI, Y., and V. W. RUTTAN (1970): "Agricultural Productivity Differences among Countries," *American Economic Review*, 60, 895-911.

— (1985): *Agricultural Development: An International Perspective*. Baltimore and London: Johns Hopkins.

HCSO (2005): *Statistical Yearbook of Agriculture 2004*. Budapest: Hungarian Central Statistical Office.

HIGGINS, J. (1986): "Input Demand and Output Supply on Irish Farms: A Micro-Economic Approach," *European Review of Agricultural Economics*, 13, 477-493.

HOLZMAN, F. D. (1955): "Unemployment in Planned and Capital Economies," *Quarterly Journal of Economics*, 69, 452-60.

IDF (1992): "Central European Dairying: Transfer from Centrally-Planned to Market-Oriented Economy," *International Dairy Federation (IDF) Special Issue*, 92, 32-37.

IFCN (2004): "Dairy Report 2004," Braunschweig: International Farm Comparison Network (IFCN), 1-152.

JENSEN, H. G., and S. E. FRANDSEN (2003): "Impacts of the Eastern European Accession and the 2003-Reform of the Cap, Consequences for Individual Member Countries," Washington DC: The 7th Annual Conference on Global Analysis.

JONGENEEL, R. (2000): "The EU's Grains, Oilseeds, Livestock and Feed Related Market Complex: Welfare, Measurement, Modeling and Policy Analysis," PhD Dissertation, Wageningen: University of Wageningen, 1-361.

— (2005): "Report on Modeling Milk and Dairy Industry in the New Member States," Wageningen: Wageningen University, European Dairy Industry Model (EDIM) Deliverable D06.03, 63.

JONGENEEL, R., N. LONGWORTH, and S. HUETTEL (2005): "Dairy Farm Size Distribution in East and West: Evolution and Sensitivity to Structural and Policy Variables," Copenhagen: Conference of the European Association of Agricultural Economists.

JONGENEEL, R., and A. TONINI (2005): "A Mixed Generalized Maximum Entropy Approach: Modeling the Primary Dairy Sectors of Czech Republic, Hungary, Lithuania and

Poland," Wageningen: Wageningen University, European Dairy Industry Model (EDIM) Working Paper 06, 43.

JOVANOVIC, B. (1982): "Selection and Evolution of Industry," *Econometrica*, 47, 153-161.

JUDGE, G. G., W. E. GRIFFITHS, R. C. HILL, H. LÜTKEPOHL, and T. C. LEE (1985): *Theory and Practice of Econometrics*. New York: John Wiley & Sons.

JUDGE, G. G., and E. R. SWANSON (1962): "Markov Chains: Basic Concepts and Suggested Uses in Agricultural Economics," *Australian Journal of Agricultural Economics*, 6, 49-61.

JUHASZ, J. (1991): "Large-Scale and Small-Scale Farming in Hungarian Agriculture: Present Situation and Future Prospects," *European Review of Agricultural Economics*, 18, 399-415.

KARANTININIS, K. (2002): "Information Based Estimators for the Non-Stationary Transition Probability Matrix: An Application to the Danish Pork Industry," *Journal of Econometrics*, 107, 275-290.

KAWAGOE, T., and Y. HAYAMI (1985): "An Intercountry Comparison of Agricultural Production Efficiency," *American Journal of Agricultural Economics*, 67, 87-92.

KEANE, M. (1991): "Changes in the Size Structure of Irish Dairy Farms," *Irish Journal of Agricultural Economics and Rural Sociology*, 14, 67-74.

KEANE, M., and P. BYRNE (1992): "Dairying in Hungary," Cork: Department of Food Economics, University College Cork, 1-38.

— (1992): "Dairying in Poland," Cork: Department of Food Economics, University College Cork, 1-38.

KENNEDY, P. (2003): *A Guide to Econometrics*. Cambridge: MIT Press.

KHAMIS, S. H. (1972): "A New System of Index Numbers for National and International Purposes," *Journal of the Royal Statistical Society*, 135, 96-121.

KISS, P., and P. WEINGARTEN (2002): "Cost of Compliance with the Acquis Communautaire in the Hungarian Dairy Sector," Halle/Saale: Institute of Agricultural Development in Central and Eastern Europe (IAMO).

KMENTA, J. (1986): *Elements of Econometrics*. New York: Macmillian Publishing Company.

KOOP, G. (2003): *Bayesian Econometrics*. Chichester: Wiley.

KORNAI, J. (1986): "The Soft Budget Constraints," *Kyklos*, 39, 3-30.

KOSTOV, P., M. PATTON, J. MOSS, and S. MCERLEAN (2005): "Does Gibrat's Law Hold Amongst Dairy Farmers in Northern Ireland?" Copenhagen: Conference of the European Association of Agricultural Economists.

KRAWIECKA, L. (2005): Personal Communication on Data on Private Dairy Farms in Poland, Warsaw: National Statistical Office.

KRENZ, R. D. (1964): "Projection of Farm Numbers for North Dakota with Markov Chains," *Agricultural Economics Research*, 16, 77-83.

KULLBACK, J. (1959): *Information Theory and Statistics*. New York: John Wiley.

KUMBHAKAR, S. C. (1990): "Production Frontiers, Panel Data, and Time-Varying Technical Inefficiency," *Journal of Econometrics*, 46, 201-211.

KUMBHAKAR, S. C., and C. A. K. LOVELL (2003): *Stochastic Frontier Analysis*. Cambridge Cambridge University Press.

LANCASTER, T. (2004): *An Introduction to Modern Bayesian Econometrics*. Blackwell Publishing.

LAU, L., and P. YOTOPOULOS (1989): "The Meta-Production Function Approach to Technological Change in World Agriculture," *Journal of Development Economics*, 31, 241-269.

LAU, L. J. (1976): "A Characterization of the Normalized Restricted Profit Function," *Journal of Economic Theory*, 12, 131-163.

LEAMER, E. E. (1983): "Let's Take the Con out of Econometrics," *The American Economic Review*, 73, 31-43.

LEDEBUR, E. O. V., and D. MANEGOLD (2004): "GAPsi Simulations Updated Baseline and EU Enlargement under the Mid-Term-Review Scenario," Braunschweig: Institut für Marktanalyse und Agrarhandelspolitik (FAL).

LEE, T. C., and G. G. JUDGE (1996): "Entropy and Mass Entropy for Estimating Transition Probabilities from Aggregate Data," in *Bayesian Analysis in Statistics and Econometrics: Essay in Honor of Arnold Zellner*, ed. by D. A. Berry, K. M. Chaloner, and J. K. Geweke. New York: John Wiley.

LEE, T. C., G. G. JUDGE, and A. ZELLNER (1970): *Estimating the Parameters of the Markov Probability Model from Aggregate Time Series Data*. Amsterdam, London: North-Holland Publishing Company, 1-254.

LEE, Y. H., and P. SCHMIDT (1993): "A Production Frontier Model with Flexible Temporal Variation in Technical Inefficiency," in *The Measurement of Productive Efficiency:*

Techniques and Applications, ed. by H. O. Fried, C. A. K. Lovell, and S. S. Schmidt. New York: Oxford University Press, 237-255.

LERMAN, Z. (2005): "Changing Farm Structure in Transition Countries in the Light of World Experience," Copenhagen: Conference of the European Association of Agricultural Economists.

LERMAN, Z., Y. KISLEV, A. KRISS, and D. BITON (2003): "Agricultural Output and Productivity in the Former Soviet Republic," *Economic Development and Cultural Change*, 51, 999-1018.

LIEFERT, W., and J. SWINNEN (2002): "Changes in Agricultural Markets in Transition Economies," Washington DC: Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture, 1-97.

LOVELL, M. C. (1983): "Data Mining," *The Review of Economic and Statistics*, 65, 1-12.

LYSON, T. A., and G. W. GILLESPIE (1995): "Producing More Milk on Fewer Farms: Neoclassical and Neostructural Explanations of Changes in Dairy Farming," *Rural Sociology*, 60, 493-504.

LYSON, T. A., and R. WELSH (1992): "Toward a Second Agricultural Devide: The Restructuring of American Agriculture," *Sociologia Ruralis*, 32, 248-263.

LUCAS, R. E. (1978): "On the Size Distribution of Business Firms," *Bell Journal of Economics*, 9, 508-523.

MACOURS, K., and J. SWINNEN (2000): "Causes of Output Decline in Economic Transition: The Case of Central and Eastern European Agriculture," *Journal of Comparative Economics*, 28, 172-206.

MASS-COLELL, A., M. D. WHINSTON, and J. R. GREEN (1995): *Microeconomic Theory*. New York, Oxford: Oxford University Press.

MATHIJS, E., and S. MESZAROS (1997): "Privatization and Restructuring of Hungarian Agriculture," in *Agricultural Privatization, Land Reform and Farm Restructuring in Central and Eastern Europe*, ed. by J. F. M. Swinnen, A. Buckwell, and E. Mathijs. Aldershot, England; Brookfield USA: Ashgate, 161-188.

MATHIJS, E., and N. NOEV (2004): "Subsistence Farming in Central and Eastern Europe," *Eastern European Economics*, 42, 72-89.

MCCLOSKEY, D. N. (1985): "The Loss Function Has Been Mislaid: The Rhetoric of Significance Tests," *The American Economic Review*, 75, 201-205.

MEEUSEN, W., and J. VAN DEN BROECK (1977): "Efficiency Estimation from Cobb Douglas Production Functions with Composed Error," *International Economic Review*, 18, 435-444.

MERGOS, G. (2002): "EU Enlargement and the Cap: A Quantitative Analysis for Slovenia and Bulgaria," Wissenschaftsverlag Vauk Kiel KG, 209.

MITTELHAMMER, R. C., and N. S. CARDELL (1997): "The Data-Constrained GME Estimator of the GLM: Asymptotic Theory and Inference," Pullman: Washington State University.

MITTELHAMMER, R. C., and R. K. CONWAY (1988): "Applying Mixed Estimation in Econometric Research," *American Journal of Agricultural Economics*, 70, 859-866.

MITTELHAMMER, R. C., G. G. JUDGE, and D. J. MILLER (2000): *Econometric Foundations*. Cambridge: Cambridge University Press.

MOONEY, C. Z., and R. D. DUVAL (1993): *Bootstrapping: A Non Parametric Approach to Statistical Inference*. Newbury Park, CA: Sage Publications.

MORRISON-PAUL, C. J., W. E. JOHNSTON, and G. A. G. FRENGLEY (2002): "Efficiency in New Zealand Sheep and Beef Farming: The Impacts of Regulatory Reform," *The Review of Economics and Statistics*, 82, 325-337.

— (2002): "Post-Reform Substitution and Cost Efficiency in the New-Zealand Agricultural Sector," *International Journal of Business and Economics*, 1, 135-146.

MOSCHINI, G. (1988): "A Model of Production with Supply Management for the Canadian Agricultural Sector," *American Journal of Agricultural Economics*, 70, 318-329.

MUNDRA, K., and R. R. RUSSELL (2004): "Dual Elasticities of Substitution: Application to the Swiss Labor Market," Riverside: University of California, 1-26.

MURILLO-ZAMORANO, L. R. (2004): "Economic Efficiency and Frontier Techniques," *Journal of Economic Survey*, 18, 33-77.

NORMILE, M. A., and S. E. LEETMA (2004): "US-EU Food and Agriculture Comparisons," Washington DC: Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture, 1-97.

OECD (1994): *Review of Agricultural Policies: Hungary*. Paris: Organisation for Economic Co-operation and Development (OECD).

— (2004): *Agriculture, Trade and the Environment: The Dairy Sector*. Paris: Organisation for Economic Co-operation and Development (OECD).

— (2004): "Producer and Consumer Support Estimates, OECD Databases 1986-2003," Paris: Organisation for Economic Co-operation and Development (OECD).

(http://www.oecd.org/document/58/0,2340,en_2825_494504_32264698_1_1_1_1,00.html, accessed: 19 January 2005)

— (2005): *Agricultural Policies in OECD Countries Monitoring and Evaluation*. Paris: Organisation for Economic Co-operation and Development (OECD).

OSKAM, A., and E. OSINGA (1982): "Analysis of Demand and Supply in the Dairy Sector of the Netherlands," *European Review of Agricultural Economics*, 9, 365-413.

OUDE LANSINK, A. G. J. M. (1999): "Generalized Maximum Entropy Estimation and Heterogenous Technologies," *European Review of Agricultural Economics*, 26, 101-115.

PARIS, Q. (2001): "Multicollinearity and Maximum Entropy Estimator," *Economic Bulletin*, 3, 1-9.

PARIS, Q., and R. E. HOWITT (1998): "An Analysis of Ill-Posed Production Problems Using Maximum Entropy," *American Journal of Agricultural Economics*, 80, 124-138.

PCSO (2005): "Agriculture in the First Half-Year of 2005 - Land Use," Warsaw: Polish Central Statistical Office (PCSO). (http://www.stat.gov.pl/english/dane_spol-gosp/rolnic_lesnict_srodowi/rolnictwo/2005/I_polr/index.htm, accessed 15 October 2005)

PERELMAN, S. (1995): "R&D, Technological Progress and Efficiency Change in Industrial Activities," *Review of Income and Wealth*, 41, 349-366.

PETIT, M., and K. BROOKS (1994): "The Role of the West in the Reconstruction of Agriculture in Eastern and Central Europe and the Former Soviet Union," *European Review of Agricultural Economics*, 21, 477-492.

PETRICK, M., and P. WEINGARTEN (2004): "The Role of Agriculture in Central and Eastern European Rural Development: An Overview," in *The Role of Agriculture in Central and Eastern European Rural Development: Engine of Change or Social Buffer?*, ed. by M. Petrick, and P. Weingarten. Halle (Saale): Institute of Agricultural Development in Central and Eastern Europe (IAMO), 1-19.

PUKELSHEIM, F. (1994): "The Three Sigma Rule," *The American Statistician*, 48, 88-91.

RAYNER, A. J. (1975): "Investment Theory, Adjustment Costs and Milk Supply Response: A Preliminary Analysis Presenting Regional Supply Functions for England and Whales," *Oxford Agrarian Studies*, 4, 131-155.

ROSEN, H. (1987): "Dynamic Animal Economics," *American Journal of Agricultural Economics*, 69, 547-557.

ROZELLE, S., and J. F. M. SWINNEN (2004): "Success and Failure of Reform: Insights from the Transition of Agriculture," *Journal of Economic Literature*, 42, 404-456.

SADOULET, E., and A. DE JANVRY (1995): *Quantitative Development Policy Analysis*. Baltimore, Maryland: The Johns Hopkins University Press.

SARRIS, A. H., T. DOUCHA, and E. MATHIJS (1999): "Agricultural Restructuring in Central and Eastern Europe: Implications for Competitiveness and Rural Development," *European Review of Agricultural Economics*, 26, 305-329.

SAUER, J., and H. HOCKMANN (2005): "The Need for Theoretically Consistent Efficiency Frontier," Copenhagen: Conference of the European Association of Agricultural Economists.

SCHMITZ, A. (1997): "Dynamics of Beef Cow Herd Size: An Inventory Approach," *American Journal of Agricultural Economics*, 79, 532-542.

SHANNON, C. E. (1948): "A Mathematical Theory of Communication," *Bell System Technical Journal*, 27, 379-423.

SHEPARD, R. W. (1970): *Theory of Cost and Production Functions*. Princetown, New Jersey: Princetown University Press, 1-308.

SOOFI, E. S. (1992): "A Generalizable Formulation of Conditional Logit with Diagnostics," *Journal of the American Statistical Association*, 87, 812-816.

STIGLITZ, J. (1993): "Incentives, Organizational Structure and Contractual Choice in the Reform of Socialist Agriculture," in *The Agricultural Transition in Central and Eastern Europe and the Former USSR*, ed. by A. Braverman, K. Brooks, and C. Csaki. Washington DC: World Bank, 27-46.

STOUT, J., and D. ABLER (2004): "ERS/Penn State Trade Model Documentation," Washington DC: Economic Research Service U.S. Department of Agriculture, 1-75.

SUHARIYANTO, K., and C. THIRTLE (2001): "Asian Agricultural Productivity and Convergence," *Journal of Agricultural Economics*, 52, 96-110.

SWENNING, R. (1999): "Enlargement of the EU with the Baltic States with and without a Cap-Reform: An Analysis within the Swopsim-Framework," Uppsala: Swedish University of Agricultural Sciences (SLU), 156.

SWINNEN, J. (2002): "Transition and Integration in Europe: Implications for Agricultural and Food Markets, Policy, and Trade Agreements," *World Economy*, 25, 481-501.

SWINNEN, J., and H. R. GOW (1999): "Agricultural Credit Problems and Policies During the Transition to a Market Economy in Central and Eastern Europe," *Food Policy*, 24, 21-47.

SWINNEN, J., and L. VRANKEN (2005): "Reforms and Efficiency Change in Transition Agriculture," Copenhagen, Denmark: Conference of the European Association of Agricultural Economists.

SWINNEN, J. F. M., and E. MATHIJS (1997): "Agricultural Privatization, Land Reform and Farm Restructuring in Central and Eastern Europe: A Comparative Analysis," in *Agricultural Privatization, Land Reform and Farm Restructuring in Central and Eastern Europe*, ed. by J. F. M. Swinnen, A. Buckwell, and E. Mathijs. Aldershot: Ashgate.

SZÁBO, M. (2000): "The Dairy Industry in Hungary. Trends and Development in the Hungarian Dairy Sector 1990-1999," *Economics of the dairy industry CEEC*, II, block 7, 32-40.

SZNAJDER, M. (2002): "I Cambiamenti Economici e Strutturali Delle Aziende Da Latte in Polonia," in *La Struttura Della Zootecnia Da Latte in Italia e in Europa* ["Economic and Structural Changes in the Polish Dairy Farms", in *The Dairy Structure in Italy and Europe*, *in Italian*] , ed. by R. Pieri, and D. Rama. Milano: Franco Angeli, 237-261.

THEIL, H. (1963): "On the Use of Incomplete Prior Information in Regression Analysis," *Journal of the American Statistical Association*, 58, 401-414.

THEIL, H., and A. S. GOLDBERGER (1961): "On Pure and Mixed Statistical Estimation in Economics," *International Economic Review*, 2, 65-78.

THIJSSEN, G. (1992): "A Comparison of Production Technology Using Primal and Dual Approaches: The Case of Dutch Dairy Farms," *European Review of Agricultural Economics*, 19, 49-65.

TOMEK, W. G., and K. L. ROBINSON (1990): *Agricultural Product Prices*. Ithaca and London: Cornell University Press.

TONINI, A., and R. JONGENEEL (2002): "Dairy Farm Size Restructuring in Poland and Hungary: Quantitative and Qualitative Analysis," in *Agricultural Enterprises in Transition: Parallels and Divergences in Eastern Germany, Poland and Hungary*, ed. by L. Hinners-Tobrägel, and J. Heinrich. Kiel KG: Wissenschaftsverlag Vauk, 317-339.

— (2005): "Combining Sample and Non-Sample Information in a Mixed Generalized Maximum Entropy Approach: Modeling the Primary Dairy Sectors of Hungary and Poland," Alexandria, VA: American Statistical Association 4110-4117.

— (2006): "Is the Collapse of Agricultural Output in the CEECs a Good Indicator of Economic Performances? A Total Factor Productivity Analysis," *Eastern European Economics*, 44, 32-59.

TOUTENBURG, H. (1982): *Prior Information in Linear Models*. New York: John Wiley & Sons.

USDA (2005): "Poland, Trade Policy Monitoring, Poland's CAP Implementation 2005," Washington DC: United States Department of Agriculture (USDA) Foreign Agricultural Service, 1-23.

VAN ZYL, J., B. R. MILLER, and A. PARKER (1996): "Agrarian Structure in Poland: The Myth of Large-Farm Superiority," Washington, D.C.: International Bank of Reconstruction and Development.

VASAVADA, U., and R. G. CHAMBERS (1986): "Investment in U.S. Agriculture," *American Journal of Agricultural Economics*, 68, 950-960.

VERBEEK, M. (2004): *A Guide to Modern Econometrics*. Chichester: John Wiley and Sons.

VIJN, P. (1980): "Prior Information in Linear Models," PhD Dissertation, Groningen: Rijksununiversiteit te Groningen, 1-173.

WAHL, O., G. WEBER, and K. FROHBERG (2000): "Documentation of the Central and Eastern European Countries Agricultural Simulation Model (CEEC-Asim Version 1.0)," Halle/Saale: Institute of Agricultural Development in Central and Eastern Europe.

WEISS, C. R. (1999): "Farm Growth and Survival: Econometric Evidence for Individual Farms in Upper Austria," *American Journal of Agricultural Economics*, 81, 103-116.

WHISTLER, D., K. J. WHITE, D. S. WONG, and D. BATES (2004): *Shazam User's Reference Manual Version 10*. Vancouver, B.C.: Northwest Econometrics.

WIIW (2001): "Transition Countries' Agriculture in 2000: Influenced by the Weather and External Developments (Summary)," Vienna: The Vienna Institute for International Economic Studies (WIIW).

— (2003): *Handbook of Statistics: Countries in Transition 2003*. Vienna: The Vienna Institute for International Economic Studies (WIIW).

ZELLNER, A. (1971): *An Introduction to Bayesian Inference in Econometrics*. New York: Wiley.

— (1988): "Optimal Information Processing and Bayesian Theorem," *American Statistician*, 42, 278-284.

— (1996): "Bayesian Method of Moments/Instrumental Variables (Bmom/Iv) Analysis of Mean and Regression Models," in *Modeling and Prediction: Honoring Seymour Geisser*, ed. by J. Lee, W. Johnson, and A. Zellner: Springer-Verlag, 448.

ZEPEDA, L. (1995a): "Asymmetry and Nonstationarity in the Farm Size Distribution of Wisconsin Milk Producers: An Aggregate Analysis," *American Journal of Agricultural Economics*, 77, 837-52.

— (1995b): "Technical Change and the Structure of Production: A Non-Stationary Markov Analysis," *European Review of Agricultural Economics*, 22, 41-60.

ZMIJA, J., and E. TYRAN (2004): "Agriculture in Southeastern Poland - Main Problems of the Systemic Transformation Process," in *The Role of Agriculture in Central and Eastern European Rural Development: Engine of Change or Social Buffer?*, ed. by M. Petrick, and P. Weingarten: Institute of Agricultural Development in Central and Eastern Europe, 73-82.

Summary

This thesis deals with the transformation of agriculture and its dairy sector for the Central Eastern European Countries (CEECs) with particular attention for Hungary and Poland. At the beginning of the 1990s, most Eastern European countries embarked on political reform: the so-called transition from a centrally planned economy to a market-oriented economy. Price liberalisation required the removal of government subsidies on production and consumption. In the early 1990s, much emphasis in the literature was given to the decline in output after reform; much less attention was paid to trends in agricultural performance and output allocation.

The EU-25 is the world's largest producer of cow's milk, with Hungary and Poland ranking respectively fifteenth and fourth in the EU-25. As a consequence of accession, the new member states (NMS) had to absorb the common agricultural policy (CAP) framework and comply with the *acquis communautaire*. Given the above, there is much interest in empirical research characterising the transformation of the dairy sector in the CEECs.

The first part of the thesis analyses the agricultural sector of several CEECs whereas the second part of the thesis analyses the dairy sectors of Hungary and Poland. The research objectives are twofold. First, the focus is on analysing the country-level performances of several CEECs during the post-socialist period. Second, the focus is on analysing the primary dairy production of Hungary and Poland, particularly their supplies and farm structures.

The research undertaken is based on aggregate country-level data. The data are sourced from FAO, OECD, and national local statistical offices. The theoretical notions used in this thesis come from neoclassical theory, which provides the main theoretical basis. The main approaches which are followed in the thesis are: stochastic production function frontier, distance function, profit function and Markov chain approaches. Maximum Entropy (ME) is the most recurrent estimation procedure used.

Chapter 2 addresses two research questions in the thesis. First it helps determining whether the collapse of agricultural output is a good indicator of economic performance for the ten CEECs which applied in 1998 for EU accession. Second it throws a light on whether countries with large-scale farming perform better than countries with small-scale farming. The chapter also provides a description of the effects of transition and the consequent agricultural adjustments. It was shown that sole reliance on the decline in agricultural output is not a suitable indicator of agricultural performance. Analyses that only focus on the output

decline in agriculture provide a partial and misleading interpretation of the success of agricultural reform in transition economies. In addition, support was found for the proposition that countries characterised by large-scale farming perform better than countries with small-scale farming.

The Baltic States plus Slovakia were the countries which experienced the greatest contraction in terms of agricultural output after transition. This was due to the negative effect of the transition reform on relatively capital-intensive agriculture. The TFP growth estimates for the ten CEECs considered in the analysis were positive, although given the sharp decline in output observed after transition it would have not been surprising to find negative growth rates. This indicates that regardless of the political and institutional break caused by transition, agricultural performance on an aggregate level nevertheless developed positively. Productivity growth was found to be entirely driven by technological change, whereas efficiency declined slightly over time. In terms of productivity growth, Slovenia was the best performing country and Latvia the worst performing country over the period analyzed. The estimated technical efficiency scores showed that, with the exception of Hungary, the remaining CEECs were on average quite far from the best-practice frontier, indicating that those countries were using a suboptimal input mix. Estimates supported the view that countries that did not demolish their large-scale farming structure tended to be more technically efficient than those following policies for small-scale farming.

Chapter 3 analyses how the transition-induced adjustments to the mix of agricultural outputs differ between Hungary and Poland. The chapter provides insights into the output substitutability patterns during the post-socialist period making it possible to examine potential allocative inefficiencies consequent to changes in relative prices. In this way, the analysis done in chapter 2 is further complemented by augmenting technical efficiency measures with several indicators about allocative inefficiencies. In addition the chapter implements a methodology able to cope with lack of data through the inclusion of constraints, which help increase the efficiency of the final estimates. From looking at the estimated output elasticities based on distance function, it appeared that over the sample under scrutiny, for both Hungary and Poland the greatest return value or productive contribution came from milk/beef/veal output. However, this contribution was lower for the 1991–1995 periods as compared to the 1996–2001 period. There is evidence for an increase in the contribution of chicken meat over time, which is expected given the positive growth rates. For the given technology further increases in chicken meat to the detriment of other outputs will be more difficult. Allocative inefficiencies were greater for Hungary than for Poland; they increased over time for Hungary, whereas for Poland they decreased. Overspecialization was found for the sugar beet production. However although chicken was increasing as well as its shadow valuation, its production was in line with market conditions. Second order substitutability measures indicated an increase in the degree of complementarity and substitutability in the second half of the 1990s. This indicates that the production relationships related to the curvature of the multi-output technology further consolidated in the second half on the 1990s as compared to the period immediately following the reform.

Chapter 4 elaborates an innovative empirical framework, which is able to recover dairy supply estimates in a context where the sample information (SI) is limited to few data points. The model reconciles information from sample data, microeconomic theory and external sources of information. In addition, it captures medium-run adjustment dynamics which are ignored in the most diffused comparative static analysis based on partial equilibrium models calibrated on guessed parameters. The way non-sample information (NSI) is introduced in the estimation through constraints was partly derived from chapter 3. A comparison of the different model results, clearly showed that without the contemporaneous enforcement of theoretical restrictions and NSI, the model would have provided spurious results. As such, for countries undergoing transformation, the use of NSI can be extremely important in extrapolating final estimates that can be soundly empirically interpreted. The quasi-fixed inputs and the related investment decision depended predominantly on the lagged levels achieved. The supply elasticities for dairy and beef were both inelastic in the short as well as in the medium run. Final estimates were not so different from those found for EU-15 countries in the pre-quota period. This confirms the expectation that although the dairy and beef farm structures differ across countries, dairy operations rely on a similar production technology. In addition it was empirically proven that the calibrated elasticities used in the literature are not far from reality.

Chapter 5 focuses on the distribution of dairy farm size for Hungary and Poland. It models how the dairy farm structures of Hungary and Poland have changed in the post-socialist period and it helps determining which dairy farms are likely to survive in the future. The projections made for the dairy farm size structure of Hungary and Poland showed that the number of dairy farms is expected to decline inexorably in the coming decades, although the number of medium and large farms is expected to increase. More precisely: in Hungary, dairy farms with 30–99 dairy cows are expected to increase, whereas in Poland, farms with more than 30 dairy cows are expected to increase. This seems to be consistent with the historical development of farm structure in those countries. For Hungary, the restructuring and modernisation of the former large collective structures is expected to gradually adjust into smaller but more viable farm units. On the other hand for Poland, the average dairy farm size is expected to grow slightly, through a process of consolidation/concentration. Subsistence farms producing cow's milk are expected to leave the sector in the next seven years in Hungary and the next fifteen years in Poland. This is likely to proceed more slowly in Poland than in Hungary, since Hungary is facing a more drastic restructuring. These findings confirmed that in the near future the dairy farm size configuration of Hungary and Poland is likely to converge to that in Europe. The outcome will depend on the extent to which the land market will be able to function properly in allocating land to the most efficient farmers. The economic environment will probably affect the process, since without robust economic conditions it is not possible to absorb the unskilled labour force in the industrial and service sectors.

The four empirical chapters (chapters 2-5) provide a picture on the agricultural performance for several CEECs as well as on the supplies and farm size structure of the dairy sector for Hungary and Poland. **Chapter 6** discusses data and caveats and methodological issues in the thesis, provides a synthesis of results, throws a light on aspects for future research and summarize the main conclusions. The regime shift that typified transition economies undermines the conventional requirements for economic modelling. During reform, not only the political and institutional system changed, but also the way statistics were organised. Thus data before transition refer to a political, economic and institutional system that differs from the post-socialist period, since both periods represent two separate economies, distinguished by their economic point of view. In addition, from a statistical point of view discrepancies due to measurement errors are observed in the literature when comparing data before and after transition. As there is insufficient data from the post-socialist period to be able to apply conventional estimation procedures, use is made of different sources of information. Information entropy econometrics is used to estimate economic models characterised by "ill-posed" and "ill-conditioned" problems. Most of the chapters rely on information theory for evaluating the information content of the parameter estimates, as well as the NSI included during estimation. The estimation perspective used in this thesis differs from the classical econometric approaches. The "maintained hypotheses" are directly introduced in the estimation ex ante. In this way, the specification search, often called "data mining" in the literature, is implicitly avoided. Both static models as well as models able to capture several dynamic elements were utilised. For countries under transformation with sudden political and institutional regime shifts, dynamic characteristics are likely to be important when analysing the evolution and equilibrium of the system under scrutiny. The chapter provides then a section in which results are synthesized; these results are also summarized in the above summary for each chapter. In the chapter, aspects for future research are listed. Arguments for further research considers either parts that could not be directly examined in the thesis because not initially planned or because it was not possible to answer them in due time.

In terms of principal conclusions the thesis, using a variety of methods, addressed all the research questions that were set out in chapter 1. In the first part it is found that TFP growth is positive for the post-socialist agriculture. However the country performances in terms of technical and allocative inefficiencies show that there is still room for improvements. In the second part particular emphasis is given to the methodological contribution of developing procedures able to cope with lack of data. External information to sample data is helpful when there is a shortage of sample data. The approach followed, allowed to recover primary supply estimates as well as the underlying dynamics of their dairy farm size distribution for Hungary and Poland. It is empirically proven that without loss of generality the calibrated elasticities used in the literature are not far from reality, and that there is complementarity between the production of milk and beef in the medium run. With respect to the dairy farm structure of Hungary and Poland, the farm number is expected to inexorably decline in the coming decade and this trend is likely to bring Hungary and Poland to a European dairy farm structure.

Samenvatting (Summary in Dutch)

Dit proefschrift gaat over de transformatie van de landbouw in de Midden en Oost Europese (MOE-) landen. Meer in het bijzonder wordt aandacht besteed aan de melkveehouderijsector en de landen Hongarije en Polen. In het begin van de negentiger jaren maakten de meeste Oost Europese landen een periode van ingrijpende politieke hervormingen mee: de zogenaamde transitie van een planeconomie naar een markteconomie. De prijsliberalisatie impliceerde de afschaffing van overheidssubsidies zowel voor wat betreft de productie als de consumptie. In de literatuur werd begin 1990 veel aandacht gegeven aan de daling van de productie na de hervorming. Veel minder aandacht werd besteed aan de prestatie en productiviteit van de landbouw en aan de veranderingen in de samenstelling van de output.

De EU-25 is 's werelds grootste zuivelproducent. Hongarije en Polen nemen binnen de EU melkproductie respectievelijk de vijftiende en vierde plaats in. Als gevolg van de toetreding, hadden de nieuwe lidstaten de plicht om het beleidsraamwerk van het Gemeenschappelijk Landbouwbeleid (GLB) over te nemen en zich in te voegen in het *acquis communautaire*. Gegeven het bovenstaande is er grote interesse in empirisch onderzoek naar de transformatie van de zuivel sector van de MOE-landen.

Het eerste deel van het proefschrift analyseert de landbouwsectoren van de verschillende MOE-landen. Het tweede deel van dit proefschrift analyseert de zuivelsectoren van Hongarije en Polen. De probleemstelling is tweeledig. Allereerst wordt gekeken naar de prestatie (performance) op nationaal niveau van de landbouwsectoren in verschillende MOE-landen gedurende de na-socialistische periode. In de tweede plaats wordt gekeken naar de primaire zuivelproductie van Hongarije en Polen, in het bijzonder naar het aanbod van ruwe melk en de bedrijfsstructuur in de melkveehouderij.

Het onderzoek is gebaseerd op geaggregeerde data op landen-niveau. De gebruikte data zijn afkomstig van de FAO, de OESO en officiële nationale statistische bureaus. De theoretische noties die worden gebruikt gaan terug op de neo-klassieke economie, die de belangrijkste basis vormt. De belangrijkste benaderingen die in dit proefschrift worden gevolgd zijn: de stochastische productie-frontier benadering, de *distance*-functie benadering, de winstfunctie benadering en de benadering via Markov-keten analyse. De meest gebruikte schattingsmethodiek is de maximum entropie-methode.

Hoofdstuk 2 gaat in op twee onderzoeksvragen. Allereerst wordt ingegaan op de vraag of de instorting van het aanbod uit de landbouw wel een goede indicator is voor de beoordeling van de economische prestatie door de sector. In de analyse worden tien MOE-landen meegenomen die in 1998 allen opteerden voor aansluiting bij de EU. In de tweede plaats werpt dit hoofdstuk licht op de vraag of landen die gekenmerkt wordt door grootschalige landbouwbedrijven het na de omslag beter doen dan landen met kleinschalige landbouwbedrijven. Het hoofdstuk geeft ook een beschrijving van de effecten van de transitie en de aanpassingen in de landbouw waartoe dit leidde. Aangetoond wordt dat de terugval in de landbouwproductie geen goede indicator is om er de prestatie of productiviteit van de landbouwsector aan af te meten. Analyses die alleen kijken naar de afname in de landbouwproductie verschaffen slechts een partieel en misleidend inzicht in het succes van de landbouwhervorming in de transitie-economieën. Er werd support gevonden voor de stelling dat de landbouw in landen met grootschalige landbouwbedrijven beter presteert dan in landen met een kleinschalige organisatie van de landbouwproductie.

De Baltische staten en Slovenië bleken de landen te zijn die het sterkst te maken kregen met een inzakkende landbouwproductie ten gevolge van de transitie. Dit werd vooral veroorzaakt door het negatieve effect van de transitie op relatief kapitaalintensieve takken van landbouwproductie. De groei in de totale factorproductiviteit (TFP)was voor alle beschouwde landen positief. Dit is opmerkelijk omdat met de scherpe daling van de productie het vinden van negatieve TFP-groeivoeten geen verrassing was geweest. Dit resultaat wijst erop dat ondanks de politieke en institutionele 'breuken' veroorzaakt door de transitie (op een geaggregeerd niveau tenminste) de prestatiescore van de landbouw zich positief heeft ontwikkeld. De productiviteitsgroei bleek volledig te worden aangedreven door technologische ontwikkeling, terwijl de efficiëntie juist in de tijd iets afnam. Slovenië was het land dat het best scoorde in termen van productiviteitsgroei; Letland deed het het slechtst. De geschatte technische efficiëntie-scores wijzen erop dat, met uitzondering van Hongarije, de meeste MOE-landen zich vrij ver van de *best practice*-frontier bevinden. Dit wijst erop dat deze landen een suboptimale mix van inputs voor de productie inzetten. De gevonden resultaten bevestigen de hypothese dat landen die hun grootschalig georganiseerde landbouwproductiestructuur niet hebben vernietigd een hogere graad van technische efficiëntie halen dan landen die in hun beleid inzetten op kleinschalig georganiseerde landbouwproductie.

In **hoofdstuk 3** wordt geanalyseerd hoe de impact van de transitie op aanpassingen in het productiepakket verschilde tussen Hongarije en Polen. Het hoofdstuk geeft inzicht in de mate van substitueerbaarheid tussen outputs in de post-socialistische periode. Dit maakt het mogelijk om na te gaan in hoeverre er sprake is van potentiële allocatieve inefficiënties samenhangend met de veranderingen in de relatieve prijzen. Op deze wijze vult de analyse in hoofdstuk 3 de analyse van hoofdstuk 2, waarin het accent op de technische efficiëntie lag, verder aan, door ook indicatoren voor de allocatieve efficiëntie te geven. Daarnaast biedt het hoofdstuk een methode om met de beperkte beschikbaarheid van data om te gaan. Dit gebeurt door tijdens het schatten extra beperkingen in ogenschouw te nemen, waardoor efficiëntere schatting mogelijk is. Kijkend naar de op de distance-functie gebaseerde outputelasticiteiten, bleek dat voor zowel Polen als Hongarije geldt dat de melk/rundvlees/kalfsvlees sector de grootste bijdrage aan de landbouwproductiewaarde leverde. In de deelperiode 1991-1995 was deze bijdrage echter kleiner dan in de periode 1996-2001. De bijdrage van de kippenvlees sector neemt over de tijd toe; een resultaat dat werd evrwacht gezien de sterke groeicijfers. Bij de gegeven technologie zal een verdere uitbreiding van de kippensector ten koste van andere sectoren moeilijker worden. De allocatieve inefficiënties waren groter voor Hongarije dan voor Polen. Voor Polen namen de allocatieve inefficiënties in de loop van de tijd af, terwijl ze voor Hongarije juist toenamen. Er is sprake van overspecialisatie in de productie van suikerbieten. Echter, hoewel de kippensector uitbreidde is de expansie daarvan in lijn met de marktcondities. De tweede orde substitutie-maatstaven gaven aan dat er in de tweede helft van de negentiger jaren zowel sprake is van een toenemende complementariteit als substitueerbaarheid. Dit wijst erop dat productietechniek en productieplannen zich in die periode lijken te stabiliseren.

In **hoofdstuk 4** wordt een innovatief empirisch raamwerk gepresenteerd waarmee het mogelijk is om het aanbodgedrag van melk te schatten in een context waarin de steekproefdata beperkt zijn tot slechts enkele observaties. Het model verenigt informatie uit de steekproef (hoeveelheid- en prijsdata), informatie afkomstig uit de micro-economische theorie en externe bronnen van informatie met elkaar. Daarnaast neemt het model de middellange termijn aanpassingsdynamiek expliciet in beschouwing, iets dat in de comparatief-statische analyse gebaseerd op, op gegiste parameters gekalibreerde, partiele evenwichtsmodellen. De manier waarop de niet-steekproefinformatie (NSI) wordt gebruikt is gedeeltelijk ontleend aan de werkwijze zoals die ook werd gevolgd in hoofdstuk 3. Een vergelijking van de verschillende geschatte modellen maakt heel duidelijk dat zonder gebruik te maken van de restricties vanuit de economische theorie en de NSI modelschatting tot niet plausibele uitkomsten leidt. Als zodanig is het gebruik van NSI cruciaal in het komen tot robuuste en plausibele empirische schattingen. Het toevoegen van de vraag naar de quasi-vaste inputs maakte duidelijk dat deze hoofdzakelijk afhankelijk zijn van de eigen vertraagde waarden. De inzet van de quasi-vaste inputs en dus de daarmee samenhangende investeringsbeslissingen bleken vooral te worden verklaard door de vertraagde quasi-vaste input variabelen. De verkregen aanbodelasticiteiten voor melk en rundvlees zijn inelastisch. Dit geldt zowel op de korte als op de middellange termijn. De uiteindelijke schattingen verschillen niet zoveel van de resultaten die zijn gevonden voor de EU-15 landen in de periode voor de invoering van de melkquota. Dit bevestigt de indruk dat hoewel de structuur van de melkveehouderij verschilt over landen, de melkveehouderij toch gebruik maakt van een gemeenschappelijke productietechnologie. Een ander resultaat is dat de empirisch geschatte elasticiteiten in dezelfde range blijken te liggen als die zijn gebruikt in de literatuur van de gekalibreerde modellen.

Hoofdstuk 5 gaat in op de verdeling van de bedrijfsgrootte in de melkveehouderij in Hongarije en Polen. In het hoofdstuk wordt gemodelleerd hoe de bedrijfsgroottestructuur van Hongarije en Polen zich heeft aangepast tijdens de na-socialistische periode. Bovendien helpt het hoofdstuk in de bepaling welke bedrijven in de toekomst waarschijnlijk zullen overleven. De projecties die werden gemaakt voor de bedrijfsgroottestructuur laat zien dat het aantal melkveehouderijbedrijven in de toekomst naar verwachting sterk zal afnemen Dit ondanks het feit dat het aantal grote bedrijven naar verwachting zal toenemen. Nauwkeuriger: in Hongarije zal het aantal bedrijven met 30-99 melkkoeien waarschijnlijk toenemen. Ook voor Polen zal het aantal melkveehouderijbedrijven in de categorie van 30 koeien of meer naar verwachting toenemen. Dit lijkt consistent met de historische ontwikkeling in de bedrijfsstructuur van deze landen.

Voor Hongarije geldt dat de herstructurering en de modernisering van de voormalige grote staatsbedrijven naar verwachting zal leiden tot een toename van kleinere bedrijven met een sterkere levensvatbaarheid. Voor Polen wordt verwacht dat de gemiddelde bedrijfsgrootte slechts traag zal toenemen en dan hoofdzakelijk door een proces van consolidatie en concentratie. De zelfvoorzieningsbedrijven die melk produceren zullen naar verwachting in de komende zeven jaar de Hongaarse landbouw verlaten. In Polen is sprake van eenzelfde aanpassingsproces, maar zal dit naar verwachting ongeveer 15 jaar duren. De reden dat dit in Polen trager gaat is dat er in Hongarije sprake is van een veel drastischer herstructurering. De gevonden resultaten bevestigen dat in de nabije toekomst de bedrijfsstructuur in Hongarije en Polen waarschijnlijk zal convergeren in de richting van die van de EU. De mate daarvan zal afhankelijk zijn van het functioneren van de grondmarkt in de heerallocatie van het land naar efficiënte boeren.

De vier empirische hoofdstukken (hoofdstuk 2-5) schetsen een beeld van de prestaties van de landbouw in de MOE-landen in het algemeen en het aanbodgedrag van en de bedrijfsstructuur in melkveehouderij in Hongarije en Polen in het bijzonder. **Hoofdstuk 6** bespreekt de dataproblemen, kwalificaties van de gevonden resultaten en methodologische zaken in dit proefschrift. Verder bevat het een synthese van de gevonden resultaten, een verkenning van toekomstige onderzoeksvragen en een samenvatting van het gedane onderzoek. De regime-omslag kenmerkend voor transitie-economieën maakt dat niet langer is voldaan aan de conventionele eisen voor economische modellering. Gedurende de hervorming veranderde niet alleen het politieke systeem, ook de manier waarop de statistieken werden verzameld en gemeten veranderde. De data voor de transformatie waren verbonden met een politiek en institutioneel systeem dat verschilde van dat van de na-socialistische periode. Beide perioden representeren twee verschillende economieën, die zich onderscheiden door een eigen economisch gezichtspunt. Daarnaast is er vanuit een statistisch oogpunt sprake van discrepanties en meetfouten in de data wanneer de gegevens van beide perioden met elkaar worden vergeleken.

Informatie-entropie-econometrie is gebruikt om economische modellen te schatten die worden gekarakteriseerd door “ill-posed” en en “ill-conditioned” problemen. In de meeste hoofdstukken wordt daarom zowel gebruik gemaakt van de informatie in de data als van niet-steekproefinformatie. In dat opzicht verschilt de schattingsmethode die is gebruikt in dit proefschrift van de klassieke econometrische schattingsmethoden. De ‘gehandhaafde hypothesen’ worden direct en ex-ante geïntroduceerd in de schattingsprocedure. Op deze wijze kan *data-mining*, het ex-post aanpassen van de schattingen op basis van priorinformatie, worden vermeden. Zowel statische modellen als modellen die verschillende dynamische elementen aankunnen werden geëxploreerd. Voor de transitie-economieën met de plotselinge politieke en institutionele schokken, is het in beschouwing nemen van dynamiek van belang als men tot een verklaring van de evolutie en het evenwicht van het systeem wil komen.

Hoofdstuk 6 bevat een paragraaf waarin de verkregen resultaten worden samengevat. Er worden ook suggesties gedaan voor toekomstig onderzoek. De gedane suggesties hangen samen met zaken die in het kader van dit onderzoek in de beschikbare tijd niet konden worden behandeld of buiten de initiële focus van dit onderzoek vielen.

De belangrijkste conclusie gebaseerd op het eerste deel van dit onderzoek is dat de groei van de TFP voor de MOE-landen in de na-socialistische periode positief is. Echter de scores wat betreft allocatieve efficiëntie laten zien dat er nog ruimte voor verbetering is. De uitbreiding van de EU stimuleert waarschijnlijk de mogelijkheden om deze ruimte ook te benutten. In het tweede deel van dit proefschrift is veel aandacht gegeven aan de methodiek om modellen te schatten in een context van ontbrekende data of de beschikbaarheid van data van matige kwaliteit. Het gebruik van externe informatie is daarbij nuttig. De gevolgde benadering maakte het mogelijk om het aanbodgedrag van de Hongaarse en Poolse melkveehouderij te schatten, alsook de aanpassing in de bedrijfsgroottestructuur. Expliciet werd aangetoond dat de op empirische basis gevonden elasticiteiten niet sterk verschilden van de gegiste elasticiteiten zoals die zijn gebruikt voor een aantal gekalibreerde beleidssimulatiemodellen. Bovendien kwam naar voren dat er op de middellange termijn sprake is van complementariteit tussen de productie van melk en rundvlees. Wat de bedrijfsstructuur betreft wordt verwacht dat het aantal melkveehouderijbedrijven in de komende tien jaar in Hongarije en Polen heel sterk zal dalen. Verder lijkt er sprake van een trendmatige ontwikkeling waarin de bedrijfsstructuur convergeert naar die van de rest van Europa.

Other related publications

Scientific papers published in peer reviewed journals

Tonini, A. and R. Jongeneel, 2006. Is the collapse of agricultural output in the CEECs a good indicator of economic performance? A total factor productivity analysis. *Eastern European Economics* 44(4), p. 32-59.

Jongeneel, R. and A. Tonini, 2003. Primary dairy production in Poland and Hungary: a structure, conduct, performance approach. *Bulgarian Journal of Agricultural Science* 9(2), p. 135-148.

Scientific papers under review in peer reviewed journals

Tonini, A. and R. Jongeneel. Dairy farm size distribution in Hungary and Poland. Submitted for publication in *Applied Economics*.

Tonini, A. and R. Jongeneel. Modelling the dairy and beef supplies for Hungary and Poland using a mixed generalized maximum entropy estimator. Submitted for publication in the *European Review of Agricultural Economics*.

Tonini, A. and R. Jongeneel. Transition-induced adjustments to the mix of agricultural outputs: A case study of Hungary and Poland. Submitted for publication in the *Journal of Agricultural and Applied Economics*.

Scientific papers published in conference proceedings

Jongeneel, R. and A. Tonini, 2005. A Mixed Generalized Maximum Entropy Approach: Modeling the Primary Dairy Sectors of Czech Republic, Hungary, Lithuania and Poland. Wageningen: Wageningen University, European Dairy Industry Model (EDIM) Working Paper 06, 43.

Bouamra Mechemache, Z., H. Hadj Ali Kein, V. Requillart, R. Jongeneel and A. Tonini, 2005. EU dairy sector: Impact of Luxemburg reform, EU enlargement and trade negotiations. In the XIth Congress of the EAAE (European Association of Agricultural Economists), *The Future of Rural Europe in the Global Agri-Food System*, Copenhagen, Denmark, August 24-27.

Tonini, A. and R. Jongeneel, 2005. Combining sample and non-sample information in a mixed generalized maximum entropy approach: Modeling the primary dairy sectors of Hungary and Poland. *2005 Proceedings of the American Statistical Association, Statistical Computing Section [CD-ROM]*, Alexandria, VA: American Statistical Association, p. 4110-4117.

Tonini, A. and R. Jongeneel, 2005. The agricultural Polish technology and output mix adjustments due to transition: a distance function approach using a restricted generalized maximum entropy estimator. In *Modelling Agricultural Policies: State of the Art and New*

Challenges, Proceedings of the 89th European Seminar of the European Association of Agricultural Economists, F. Arfini (Ed), Monte Universitá Parma, Parma, p. 440-457.

Tonini, A., 2003. Productivity growth in agriculture and intertemporal frontier separation for six CEECs and the EU-15 members. In *16th Workshop of Marie Curie Fellows: Research Training in Progress*, held at the Institute for Energy, Joint Research Centre of the European Commission, Papazoglou, T. and R. Hurst (Eds.), European Commission, Petten, p. 60-63.

Tonini, A. and R. Jongeneel, 2002. Dairy farm size restructuring in Poland and Hungary: quantitative and qualitative approach. In *Agricultural Enterprises in Transition: Parallels and Divergences in Eastern Germany, Poland and Hungary*, L. Hinners-Tobragel and J. Heinrich (Eds.), Wissenschaftsverlag Vauk, Kiel, p. 317-339.

Congress presentations

Tonini, A. and R. Jongeneel, 2005. A Mixed Generalized Maximum Entropy Approach: Modeling the Primary Dairy Sectors of Czech republic, Hungary, Lithuania, and Poland. Contributed paper and presentation, NAKE (Netherlands Network of Economics) Day 2005, Dutch Central Bank, Amsterdam, October 21, 2005.

Tonini, A. and R. Jongeneel, 2005. Combining sample and non-sample information in a mixed generalized maximum entropy approach: Modeling the primary dairy sectors of Hungary and Poland. Paper prepared for presentation for the Conference in Honor of George Judge, The 2nd Conference on Information and Entropy Econometrics: Theory, Method, and Applications, Washington DC, District of Columbia, USA, September 23-25.

Tonini, A. and R. Jongeneel, 2005. The agricultural Polish technology and output mix adjustments due to transition: a distance function approach using a restricted generalized maximum entropy estimator. Paper prepared for presentation at the 89th Seminar of the EAAE (European Association of Agricultural Economics), Modelling Agricultural Policies: State of Art and New Challenges, Parma, Italy, February 3-5.

Tonini, A. and R. Jongeneel, 2004. Measuring TFP growth and convergence in agriculture for the former EU-15 countries and a selected number of CEECs: A stochastic frontier approach. Paper prepared for presentation at the 91st Seminar of the EAAE (European Association of Agricultural Economics), Methodological and Empirical Issues of Productivity and Efficiency Measurement in the Agri-Food System, Rethymno, Creta, Greece, September 24-26.

Tonini, A., 2003. Productivity growth in agriculture and intertemporal frontier separation for six CEECs and the EU-15 Members. Contributed paper and presentation, NAKE (Netherlands Network of Economics) Day 2003, Dutch Central Bank, Amsterdam, October 24.

Tonini, A., 2003. Productivity growth in agriculture and intertemporal frontier separation for six CEECs and the EU-15 Members. Contributed paper and presentation, 16th Workshop of Marie Curie Fellows: Research Training in Progress, DG JRC Institute for Energy, Petten, The Netherlands, October 21-22.

Tonini, A. and R. Jongeneel, 2003. The Polish dairy sector joining the EU: Modeling and policy analysis. Contributed paper and presentation, European Doctoral Meeting on Food, Agriculture, Environment & Development in Economics, Business & Social Sciences, Montpellier, France, June 19-20.

Tonini, A. and R. Jongeneel, 2002. Restructuring of Polish and Hungarian dairy farms. Contributed paper and presentation, Agricultural Enterprises in Transition: Parallels and divergences in Eastern Germany, Poland and Hungary, IAMO, Halle, September 29-30.

Tonini, A. and R. Jongeneel, 2002. The potentialities of the Polish and Hungarian dairy sectors. Contributed poster paper, 26th IDF World Dairy Congress, Paris, France, September 24-27, 2002.

Tonini, A. and R. Jongeneel, 2002. Reconfiguration of the Polish dairy farm sizes. Contributed poster paper, 10th Congress of the EAAE (European Association of Agricultural Economists), Exploring diversity in the European Agri-Food System, Zaragoza, Spain, August 28.

Completed Training and Supervision Plan

Name Axel Tonini

PhD student, Mansholt Graduate School (MGS)

Completed Training and Supervision Plan

Name of the course	Department/Institute	Year	Credits
I. General part			
Written English	CENTA[1)]	2002	2
Techniques for Writing and Presenting a Scientific Paper	Mansholt Graduate School	2002	1
Subtotal part I			3
II. Mansholt-specific part			
Mansholt Introduction course	Mansholt Graduate School, The Netherlands	2001	1
Mansholt Multidisciplinary Seminar	Mansholt Graduate School, The Netherlands	2004	1
Presentations at (international) conferences etc.:			
	EAAE[2)] conferences, Zaragoza and Copenhagen	2002, 2006	2
	EAAE[2)] seminars, Rethymno and Parma	2004, 2005	
	European doctoral meeting, Montpellier	2003	
	IAMO[3)] conference, Halle	2002	
	IDF[4)] congress, Paris	2002	
	16^{th} Workshop of Marie Curie Fellows, Petten	2003	
	IEE[5)] conference, Washington DC	2005	
Subtotal part II			4
III. Discipline-specific part			
Econometrics II	Mansholt Graduate School, The Netherlands	2002	3

Advanced Microeconomics	London School of Economics, United Kingdom	2002	4
Agricultural Economics Models	Mansholt Graduate School, The Netherlands	2002	5
Applied Policy Analysis	NAKE[6)]	2002	2
Parametric and Non-Parametric Methods in Efficiency and Productivity Analysis	NAKE	2003	2
New Economic Geography	NAKE	2003	2
Summer School on Efficiency and Productivity Analysis	Mansholt Graduate School, The Netherlands	2003	4
Macroeconomics I	Tilburg University, The Netherlands	2003	5
Econometrics of Panel Data	NAKE	2004	2
Information and Entropy Econometrics Theory and Practice	Mansholt Graduate School, The Netherlands		2
NAKE Workshops	NAKE	2002, 2002, 2004	6
NAKE Research Day	NAKE	2003, 2005	2
Subtotal part III			39
Total (minimum 20 credits)			46

[1)]CENTA is the language centre of Wageningen University and Research Centre; [2)] EAAE is European Association of Agricultural Economists; [3)] IAMO is Institute of Agricultural Development in Central and Eastern Europe; [4)] IDF is the International Dairy Federation; [5)] IEE is the acronym for Information Entropy Econometrics; [6)] NAKE is the Netherlands Network of Economics.

Curriculum vitae

Axel Tonini was born September 24th, 1974 in CastelSanGiovanni (Piacenza), Italy. After attending the “Liceo Scientifico Statale Lorenzo Respighi” in Piacenza, he completed his undergraduate studies at the “Universitá Cattolica del Sacro Cuore” in Piacenza, where he obtained in 1999 the degree with *magna cum laude* in Agricultural Sciences with a field in animal sciences. He graduated from the “Instituto di Economia Agro-alimentare” with a thesis entitled “Gestione della Qualitá ed Indicatori di Qualitá nell’Esperienza Italiana e Francese” prepared under the supervision of Dr. Daniele Rama. After obtaining his degree, he continued his graduate studying at the “Scuola di Specializzazione del Sistema Agro-alimentare” at the “Universitá Cattolica del Sacro Cuore” in Cremona. After the first year of his specialization in 2000, he was admitted to proceed in the second year as an exchange graduate student at the Department of Agricultural Economics of the University of Guelph, Ontario, Canada. During his stay in Canada he wrote a thesis entitled “Una Valutazione Economica del “Net Income Stabilization Account” (NISA) in Ontario” prepared under the supervision of Dr. Harry Cummings and Dr. Daniele Rama. He was awarded of the “XLII — Agostino Gemelli” Prize – “Ludovico Necchi” from the Catholic University of Sacred Heart Association, Milan, Italy as the best outstanding graduate student for the year 2001. In October 2001, he won a competitive examination to start his doctoral degree in “Economia e Politica Agraria” at the “Universitá degli Studi di Padova.” During the start of his Doctoral degree in Italy he was awarded of a Marie Curie Host Fellowship within the “Marie Curie Training Site Mansholt Intitute, Consumer-oriented Chains” which made possible for him to receive course training at Wageningen University. During this period he worked on a PhD research proposal for analyzing the transformation of the dairy sector of Hungary and Poland during the accession to the European Union. In February 2002 he officially started a PhD program at the Agricultural Economics and Rural Policy Group of Wageningen University, under the supervision of Dr. Roel Jongeneel. Since then he was sharing his research between his Italian doctoral degree and his PhD program in Wageningen. In 2004 he successfully completed the doctoral training programme of the Netherlands Network of Economics (NAKE). In 2005 he obtained his Doctoral degree from “Universitá degli Studi di Padova”, with a thesis entitled “Il Settore Agricolo Polacco e Ungherese con Particolare Enfasi sul Settore della Produzione di Latte” under the supervision of Dr. Daniele Rama.

Printer

Ponsen & Looijen BV, Wageningen

Financing organisations

Marie Curie Training Site "Chains" of Mansholt Graduate School (financed by the European Union)

A research grant of Mansholt Graduate School (Wageningen University)

European Dairy Industry Model a European Commission project financed by the 6th framework

LEB fund (Wageningen University) for conference attendance.