Are Cashew Grades and other Tree Nut Prices linked?

A study on market linkages between different cashew kernel grades and walnut, pistachio and almond kernels

WW320 Cashews (CEPCI 2013)  
LWP Cashews (CEPCI, 2013)

Almonds (ABC 2013)  
Pistachios (APG 2013)  
Walnuts (WBC 2013)

Raw Cashew Nut and Apple (Author)  
freshly shelled Cashew kernels (Author)
Are Cashew Grades and other Tree Nut Prices linked?

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**Foreword**

I have created this report for the course AEP 80433. Confidentiality is evaluated in mid of June 2013 (Foretell Business Solution).

**Acknowledgement**

I appreciated the opportunity to research my thesis with the ACi. The organization has supported my general understanding of the cashew market in more ways that I am able to put in words. In fact a variety of organizations or rather persons have supported my research. I have received interesting ideas from so many perspectives that I was hardly able to keep a narrow research scope. In the end I followed Samson Trading’s motto “to go nuts about cashew” (Samson Trading Ltd.), otherwise I might still be working on it. This put me on the edge of drinking coffee. Luckily I made it through. Thanks to all of you.
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**Abbreviations**

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<th>Description</th>
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<tr>
<td>ABC</td>
<td>Almond Board California</td>
</tr>
<tr>
<td>ACA</td>
<td>African Cashew Alliance</td>
</tr>
<tr>
<td>ACi</td>
<td>African Cashew initiative</td>
</tr>
<tr>
<td>APG</td>
<td>American Pistachio Growers</td>
</tr>
<tr>
<td>C&amp;F</td>
<td>Cost and Freight</td>
</tr>
<tr>
<td>CNSL</td>
<td>Cashew Nut Shell Liquid</td>
</tr>
<tr>
<td>DCCD</td>
<td>Directorate of Cashew nut and Cocoa Development</td>
</tr>
<tr>
<td>DF</td>
<td>Dickey Fuller test</td>
</tr>
<tr>
<td>FOB</td>
<td>Free On Board</td>
</tr>
<tr>
<td>IPA</td>
<td>Iranian Pistachio Association</td>
</tr>
<tr>
<td>KOR</td>
<td>Kernel Outturn Ratio</td>
</tr>
<tr>
<td>KSCDC</td>
<td>Kerala State Cashew Development Corporation</td>
</tr>
<tr>
<td>Lbs.</td>
<td>Pound</td>
</tr>
<tr>
<td>LWP</td>
<td>Large White Pieces</td>
</tr>
<tr>
<td>RCN</td>
<td>Raw Cashew Nuts</td>
</tr>
<tr>
<td>ROW</td>
<td>Rest Of World</td>
</tr>
<tr>
<td>VECM</td>
<td>Vector Error Correction Model</td>
</tr>
<tr>
<td>WBC</td>
<td>Walnut Board California</td>
</tr>
<tr>
<td>WW</td>
<td>Whole White</td>
</tr>
<tr>
<td>WW320</td>
<td>Cashew pack of wholes with a nut count below 320 per pound</td>
</tr>
</tbody>
</table>
Executive Summary
Cashew prices are volatile (Phipps, 2010) and have increased during the last decade (Figure 1). This causes uncertainty among traders and actors in the cashew industry. They begin to suspect that consumers replace cashew with comparable products. Economically, those comparable products are demand substitutes, hence their prices are connected (Hunter, 2008, p.4). This study examines price relations between cashew grades, walnuts, pistachios and almonds. This includes the relation between broken and whole cashew grades. Two grade types that are positioned differently on the consumer market (section 2.1.3). They are distinguished in the investigation of demand substitution among tree nuts.

In the cashew value chain, there are two main trade stages (Figure 2). India has been the largest raw cashew nuts (RCN) producer (Fitzpatrick, 2011) and trader in 2010 with a share of 89.4 % of global imports (UN-Comtrade 2013). After trade RCN are processed into kernels (Figure A2 Appendix), yielding different whole and broken cashew grades (Table 1). Most kernels derive from India with a share of 63 % in globally processed kernels (section 2.1.2). Following the kernel trade whole cashew grades are dominantly roasted and marketed as a snack (section 2.1.3.1); while broken grades are used as ingredient in the value chain of other food products (section 2.1.3.2). In India other major tree nut markets are pistachio, almond and walnut (Mathew et al., 2011, p.159). Actors and traders in all four commodities try to position their product as snack and ingredient (section 2.2.3).

The utilized prices in this study are gathered from Cashew-Info bulletin. Prices for the different tree nuts refer to Delhi, India. Prices for different cashew grades are surveyed at port levels in Cochin and Tuticorin, India (Table 4). The price spread between the broken cashew grade LWP and the whole grade WW320 is regressed upon time, while time series properties of the variables is accounted for (section 3.2.1). Then substitution between those two grades and other tree nut prices is tested in a cointegration framework. In the short run price shocks might not be immediately transmitted to substitutes, hence I choose cointegration analysis which allows for testing long run relationships (section 3.2.2).

The price spread between whole and broken cashew grades reveals a highly significant time trend over the period of 06/2003 to 11/2012. The two grade prices are drifting apart (table 6). The cointegration framework cannot confirm any inter-commodity market link. All prices appear unrelated in the long run (section 4.2).

Conclusively, broken and whole cashew grades are related in supply, while their demand is very differently developed (section 2.1.3.2). Broken grade prices become relatively cheaper every month. One option for processors is to develop international demand for broken kernel grades. The price of cashew is driven by supply and demand. Cashew supply resembles other tree nuts in terms of harvest volumes. In terms of demand other tree nuts, e.g. almonds, are more effectively positioned as food ingredient (section 2.2). In regard to snacks, a roasted nut can be replaced in nut mixes and the final consumer’s preference can depend on relative prices of nut packages. However, these potential shifts are not sufficient to find economic substitution according to Hunter (2008, p.4). Market actors and traders should focus on other factors, as comparable commodity prices are not a significant price driver.
1. Introduction

“The cashew tree is evergreen” (Azam-Ali 2002, p.1). It is a tropical tree that produces the worldwide known cashew nuts. Cashew has the potential to become an important global commodity in the future. It can generate employment, export revenues in developing countries (Kanji 2004) and may be used as source of protein. Up to today the market has been challenging to its actors in multiple ways. Cashew prices have not been stable. Even during one year monthly prices can vary greatly. In 2008 the maximum monthly free on board (FOB) port price, in Cochin, was at 3.36 $/lbs., while the minimum price was at 2.23 $/lbs. (Phipps 2010). Figure 1 merely provides annual averages for the most common whole white (WW) cashew kernels. Additionally to volatility the market comprehends an upward trend in prices since 2004 (Figure 1). Prices have increased gradually (Mathew et al., 2011, p.140), as demand grows quicker than supply. This has caused worries and uncertainty among traders and actors in the cashew industry. The dominant fear is that consumers will lose interest in their product and substitute it.

“Demand substitution occurs when buyers regard two products as providing the same value in their end use. [...] A price increase is unprofitable as a result of demand substitution because many customers would switch from the higher priced products to the lower priced product” (Hunter 2008, p.4). In regard to cashew a comparable product might be other tree nuts. In India the most common tree nuts are cashew, almond, walnut and pistachio (Mathew et al., 2011, p.159). In case of substitution commodity prices develop with interdependency, i.e. prices maintain equilibrium. In the short term this equilibrium can be disturbed due to a price shock of a substitute, but in the long run prices are connected and show simultaneous developments. It is common to find such a substitution relationship among different grades of one commodity.

Cashew kernels are available in a large variety of grades. These grades can be classified in broken and whole grade types (Table 1). The two grade types are positioned differently on the consumer market (section 2.1.3). Both types are potentially substituted by other tree nuts. Both types might be potential substitutes for each other despite different positioning on the consumer market. Broken grades have the same nutritional value but look less attractive (Cover Page - LWP Cashews). Those grades are increasingly discussed. The cashew processing industry progressively considers full mechanization (Mathew et al., 2011, p.81). The mechanization of nut shelling yields a higher supply of broken cashew nuts. On the contrary wholesalers talk about increasing the usage of broken nuts, leading to an increase in demand. This raises not just the question whether a constant relationship exists among the grades, but also how a potential trend between prices would be directed. This leads to the research objective, which is to identify substitution and price trends in the cashew market. More explicitly this research intends to find evidence for the substitution of cashews by other tree nuts and a significant trend between cashew grades. The study is based on the following research questions:
1. What is the price development of broken cashews relative to whole cashews?
2. Are cashew grades substituted by almonds, pistachios or walnuts?

To analyse and answer the research questions price variables are selected for kernels of different cashew grades and different tree nuts. India is the largest producer and consumer of cashew in the world (Fitzpatrick 2011). The country is well connected to the global market, as major importer and exporter in the cashew sector. An Indian perspective on supply limits the potential location for price observations. Chapter 2 clarifies the Indian cashew value chain to understand the context of price variables. Equally chapter 2 depicts the other tree nuts and compares them to the cashew value chain. The subsequent methodology chapter explains data collection, data management and introduces the selected price variables. The chapter also clarifies the econometric approach to tackle the research questions. The price spread between whole and broken cashew grades is analysed in regard to time trends. And a cointegration approach is applied to test for substitution between prices. The cointegration is examined in the context of a multivariate time series model. In case of cointegration a vector error correction model (VECM) can specify the different cointegration relationships and confirm market linkages. The chapter results summarizes the outcome of these econometrical efforts. The final chapter discusses the methodology and results based on all previous chapters.
2. The global cashew market from an Indian perspective

This chapter describes the cashew market from an Indian perspective. Section 2.1 briefly zooms in on the different supply chain stages. This description influences the selection of cashew prices throughout this research. The section also supports the interpretation and discussion of obtained results, while it emphasizes the position of broken nuts in the value chain. Section 2.2 compares the supply chain features of cashew to pistachio, walnut and almond. This reveals inter-commodity differences and similarities

2.1. Cashew supply chain

Figure 2 Cashew supply chain

Figure 2 is based on Ruben et al. (2007), who elaborates the cashew value chain for the case of production and processing in Kerala (India) until the kernels are traded and consumed in the Netherlands. The information selected in section 2.1 is not limited to this kernel trade in particular. The Indian raw cashew nuts (RCN) and kernels are traded domestically and internationally with a variety of trading partners. Researched prices refer to domestic and international trade in kernels before value is added in form of roasting etc., i.e. cashew processors look for sales to roasters, traders and other value adding companies. Compared to Ruben et al. (2007) I explicitly distinguish the use of cashew as ingredient in other food products from the typically roasted cashew snack (Figure 2). This emphasizes the different consumption patterns of whole and broken cashew nuts. The section starts with raw nut production.

2.1.1. Raw nut production and trade

A cashew tree has modest soil requirement. It tolerates a wide range of moisture levels and soil types (Azam-Ali 2002). The tree needs between 3 to 4 years until it begins to bear fruit (DCCD 2012). Consequentially supply responses to price incentives are delayed, which results in a rather inelastic supply. RCN harvest continues all year long in different locations all over the world, which emphasizes the global nature of cashew supply. India’s harvest season lasts from February to July (Phipps 2010).

Global harvest quantities have surpassed the 2,000,000 tonnes milestone in 2005 (Figure A1 Appendix). Recent growth in supply is predominantly accountable to African supply growth. In 2011 Africa’s production level has exceeded the milestone of 1,000,000 tonnes, while in 2004 the production level was below 500,000 tonnes (Figure A1 Appendix). Nevertheless India remains the largest producer followed by Ivory Coast, Vietnam and Brazil (Fitzpatrick 2011). India cannot cover...
domestic demand of raw nut processors. It is the major importer with an 89.4 % share of the global RCN imports in 2010 (UN-Comtrade 2013). The imports derive from Africa and Indonesia (Mathew et al., 2011, p.180); while the domestic production is located in the south of India (DCCD 2012). The imported RCN arrive predominantly in Kerala and Tamil Nadu (map, Figure 4); receiving 96% of India’s imports in 2005-2006 (Table A1 Appendix). The main ports in these states are Cochin (Kerala) and Tuticorin (Tamil Nadu) (map, Figure 4). The ports are useful references for trade prices. They present a bottleneck for a large amount of RCN and kernel passing the value chain.

The post-harvest treatment involves basic steps. The raw nut is separated from the cashew apple, which accounts for 80 % of the fruit’s weight. The apple is often disposed. In Goa, India, the cashew apple is used to distil liquor referred to as “feni”. There are several attempts to utilize it in juice, jam, liquor, due to its high nutritional value, but 95 % of cashew apples are not consumed, due to its taste (Yadav 2010) and logistic challenges. Only Brazil, Mali and Madagascar do report cashew apple produce (FAO, 2013). Conclusively the cashew apple does not withhold much economic value, yet. Next post-harvest activity is the drying of the nut to reduce the moisture content below 10 % to avoid rotting during storage (Masawé et al., 2011). Economically, correct drying is equally important to ensure an optimal shelling and reduced brittleness of the nut (Hebbar and Ramesh, 2005).

2.1.2. Processing into kernels and trade
Processors create cashew kernels out of RCN. They are the key intermediaries between agricultural producers and final consumer. Processors incur the highest cost in terms of value added at the secondary stage (Srivatsava et al., 2008, p.203). The basic economic features of processing are (Pal 2009):

• the yield, i.e. kernel outturn ratio (KOR), usually given in kernel pounds per 80 kg RCN matter
• the costs of processing
• cashews grades by appearance attributes (see also Table 1):
  o the percentage of whole kernels in shelled\(^1\) nut weight
  o the whiteness preserved after processing

Figure A2 in the Appendix indicates the process flow of RCN processing. Shelling is key step in processing. It can be done manually, half-mechanized or mechanical and determines to a large extent the percentage of whole kernels achieved in processing. A fully mechanized shelling can leads to about 55% wholes at the packaging stage, while the manual shelling achieves 70-75% wholes (Mathew et al., 2011, p.135).

Table 1 presents an example of a graded outturn of an RCN batch controlled by Technoserve\(^2\). The shelling has been done half-mechanized. The yield of the batch was 24 %. Thereby the RCN weight equals 4-4.2 times the kernel weight. Size is determined by counting the maximal kernel number per pound or sieving the broken cashews. WW320 (see abbreviations) and large white pieces (LWP) are representative grades analysed throughout this research. Example prices for different grades are given in US dollar per lbs. The sources are collated to the column which they provide information on.

\(^1\) shelled = a nut without shell, in shell = a nut with shell

Table 1 Grade classification, share and value

<table>
<thead>
<tr>
<th>Grade</th>
<th>Size (nut count no. /lbs.)</th>
<th>% in a batch outturn</th>
<th>$/lbs., Cochin 05/19/2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholes Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WW</td>
<td>Whole kernels</td>
<td>71.73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>whole white kernels</td>
<td>240</td>
<td>10.62</td>
</tr>
<tr>
<td></td>
<td>whole white kernels</td>
<td>320</td>
<td>33.78</td>
</tr>
<tr>
<td></td>
<td>whole white kernels</td>
<td>450</td>
<td>17.75</td>
</tr>
<tr>
<td></td>
<td>scorched whole kernels</td>
<td>All sizes</td>
<td>9.58</td>
</tr>
<tr>
<td>SW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brokens Total</td>
<td>(large) pieces, incl. Splits</td>
<td>28.27</td>
<td></td>
</tr>
<tr>
<td>LWP</td>
<td>Large white pieces</td>
<td>10.75</td>
<td>2.30 to 2.40</td>
</tr>
</tbody>
</table>


The outturn for any grade does not differ by more than 5% from an Indian study (Prasad 2001, p.328). WW 320 represents about 33.78% (Pal 2009) of a processed batch. Therefore it is the most common standard cashew grade for wholes. LWP is the most common broken grade with a share of 37% among broken nuts. The price gap between whole nuts and pieces is larger than the gap of scorched and white kernels, which emphasizes the whole percentage as one economic key factor.

Note cashew classification for whole and broken grades exceed the here represented ones. These are merely the ones mostly found in the outturn of a batch.

In India, the availability of cheap labour and the relatively lower percentage of whole nuts in mechanization have resulted in a predominantly manual or half mechanized processing industry (Yadav 2010). Contrary Brazil uses full mechanization in processing, which is increasingly considered worldwide, due to increasing labour costs. Nevertheless other processing features vary greatly even within India (Mathew et al., 2011, p.79-80). The value addition of processing (Figure A2 Appendix) can be roughly estimated with the help of a Cashew-Info handbook (Srivatsava et al., 2008, p.135).

The average Kernel price in Jeypore Orissa in 2007 was 1.37 $/kg in kernels, while the average RCN price in Jeypore was 1.01 $/kg kernel equivalents\(^4\), thereby 73% of the kernel price is imputed by the raw material. Conclusively raw nuts are the most important factor driving costs in processing. Other revenues in processing derive from cashew nut shell liquid (CNSL). These revenues are comparably marginal. In 2007 CNSL quantity accounts for about 7%, while its value only accounts for 0.5% of the cashew kernel exports in India (Yadav 2010).

\(^3\) Price refers to SW 320

\(^4\) RCN weight given in kernel equivalent weight, kernel weight = RCN weight/4.2
Geographically most of the global processing is done in the south of India. India’s cashew kernel volume was about 340,000 tonnes in 2009-2010 (Figure 3). In comparison to a global RCN market of 540,000 tonnes kernel equivalents in 2010 (Figure A1 Appendix). Conclusively India had a share of 63% in the global cashew kernel market. Indian’s processors have experienced a period of growth. The following map (Figure 4) shows that the processing facilities are located in India’s south. The raw data can be found in Table A1 in the Appendix. Again processed RCN are divided by 4.2 to estimate kernel equivalent production in each state. The map (Figure 4) shows most kernels derived from Kerala and Tamil Nadu.

![Figure 3 Indian kernel volumes](image)

**Source:** (Mathew, Singh et al. 2011, p.183)

They accounted for about 215,000 tonnes. The whole Indian kernel market was around 284,600 tonnes. In these regions Cochin and Tuticorin represent the major ports and important transition points for a large amount of cashew kernels in the sector\(^5\). Worldwide India is the second biggest exporter after Vietnam (UN-Comtrade 2013). Quantity is exported free on board (FOB) or via cost

\(^5\) Only retrieved data from 2002: Between April 2001 and March 2002 Cochin and Tuticorin port accounted for about 90% of all India’s cashew kernel exports (CashewInfo Vol.1 Issue 15)
and freight (C&F) prices (CEPCI 2013). With the latter price the supplier has to bear cost of transportation to destined port. Receiving importers of cashew kernels are all over the world. The main ones in terms of quantity are USA, EU, China, UAE (Figure A3 Appendix). Rest of the world (ROW) has the largest share in imports, which emphasizes the diversified demander regions.

2.1.3. Post processing

Based on Figure 2 the kernel can take two different paths after processing. One leads to roasting of the nut, either domestically or after export, while cashew remains the key output. The outturn is often referred to as a cashew “snack”. It is estimated that a minimum of 60 % of overall cashew kernels are consumed as salted nuts (Azam-Ali 2002). The other path reflects the opportunity for cashew to be used in other food value chains as an “ingredient”. Altogether this section elaborates on possible value adding processes and consumption of cashew as a snack or ingredient.

2.1.3.1. Snack

“The economic development of cashew has always been linked to its universal recipe development as a snack by deep fat frying”, served as a table nut (Mathew et al., 2011, p.134). The fried nuts are salted, sugar coated, spiced, masala fried etc. India exhibits also preferences for non-fried nuts, i.e. direct consumption. After roasting the snack is often marketed in a mixture with other nuts (Srivatsava et al., 2008, p.185). The roasting and packaging of the snack is commonly done in one unit. Theoretically these units can monitor the percentage of each nut in their roasting mix; practically they abide contracts with wholesalers. The packagers apply naming for the wholesalers or their very own roaster brand. But no cashew brand has been implemented by Indian suppliers to better market Indian cashews in foreign markets (Mathew et al., 2011, p.164). “There is a long way to go to generate sufficient surpluses in cashew that can lead to marketing” (Srivatsava et al., 2008, p. 204). In OECD countries the highest surpluses are in retailing which takes off up to 45 to 50% of the shelf price of a cashew pack (Srivatsava et al., 2008, p.203). Hence a lot of market power lies within the retail units. They possess the most potential to implement changes in the supply chain. Regardless of the surplus share consumption pattern always depend on what the consumer purchases. The final consumed cashew snack types vary over countries and consumers. E.g. in the USA honey roasting has been a somewhat successfully marketed product (Mathew et al., 2011, p.134). A Spanish retail study (Cashew-International-Inc. 2009) has sampled cashew snacks in different stores. They found fried and salted as dominant snack type with a share of 73 %, while fried with honey was around 7%. In the same study no broken cashew grades were found on the snack market, but about 7% so called Splits and Butts.

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6 However India is ranked main consumer of cashew over the first decade of this century; followed by cashew importers (Cashew-Info Volume 13 Issue 29).
7 Splits refer to naturally horizontally broken nuts, see also cashew specifications CEPCI. (2013). “Commercial Information.” from Cashew Export Promotion Council India (CEPCI)-
2.1.3.2. Ingredient

The retail does not favour broken cashews for the snack consumption type. “Small broken grades—bits and small white pieces—will always be more difficult to sell for direct consumption. For this reason, it is important to develop secondary uses for (broken) cashews. Cashew nuts are used in pastries, breads, cakes, meals (in salads, soups, sauces, chicken-based main dishes, and deserts), etc.” (Boillereau and Adam, 2007, p. 33). In order to structure ingredient use the cashew handbook (Mathew et al., 2011, p.136) introduces 7 segments:

- (Caramelised) cashews in chocolate, e.g. Cadbury-Kraft Foods
- Sweets, e.g. “Kaju Katli”
- Savouries
- Baking
- Confectionary
- Kitchen
- Catering

In India these segments are exploited. Tens of thousands bakeries and confectionaries use cashew in standard baked products or cookies. Sweets like Kaju Katli are very popular. Overall the current trend suggests that cashew usage as an ingredient has expanded since the 1990’s (Mathew et al., 2011, p.134). Internationally cashew is not so popular in these segments. Tree nuts in chocolate or bakery items are rather hazelnut or almond than cashew. The cashew handbook concludes that there is no market for broken grades in Europe or USA (Mathew et al., 2011, p.135), which are the biggest importers (Figure A3 Appendix). Nevertheless there are discussions on-going to integrate broken grades in other products, given the large incidental supply (Table 1), especially in case of fully mechanized processing types (section 2.1.2). One result of these discussions is the “cashew cluster” product, introduced by Kraft Food.

The supply chains can differ between segments and within the individual products. The research scope is too narrow to analyse supply chains with cashew in secondary use. Note that incentives to integrate cashew are often controlled by wholesalers or retail, which have different departments functioning in regular patterns. An exception for an incentive not deriving from this stage is Kerala State Cashew Development Corporation (KSCDC). Being the biggest processor of cashew in the world they took the initiative to produce value added products from cashew, like cashew soup powder (Srivatsava et al., 2008, p.84).

2.2. Comparable products

Based on the dominant use of cashew as a snack (section 2.1.4.1) comparable products are all kind of snacks, e.g. potato chips, peanuts or other tree nuts. While potato chips or peanuts are very different products in terms of supply chain and supply quantities, I assume potential similarities with other tree nuts. Different tree nuts are hazel, macadamia, brazil, pecans, pine, almond, pistachio and walnut. The three latter nuts are considered substitutes in my research. While cashew’s market share in India is around 75-80% in shell weight, the other three tree nuts share the rest of the market in terms of consumption volumes. Almond is about 15%, walnut about 5% and pistachio around 3% (Mathew et al., 2011, p.159). Pistachio consumption has the fastest growing rate in India. This section exhibits striking differences and similarities in a normative matter. The section supports the interpretation of research results. The main rubrics compared are supply data, production and
processing, and post processing, i.e. information on the nut after shelling and grading (see Figure A2 Appendix).

### 2.2.1. Market data

The compared market data is summarized in Table 2. Main origin refers to largest producer(s) of the raw nut. Supply and Indian demand quantities are given in kernel weight. Walnut quantities in Figure A5 in the Appendix are transformed from in shell to kernel weight by multiplication of 0.55, because the kernel weight to nut ratio varies between 46.1 and 64.2 % (Akca 1994). Similar it is done for pistachio and cashew. Cashew data from Figure A1 (Appendix) is adjusted by the factor 0.24, the kernel to nut ratio (Table 3). Almond data is retrieved in kernel weights. Global annual supply growth is calculated with the help of the raw data retrieved from African Cashew Alliance (ACA) and US Department of Agriculture (USDA). The sources are collated to the column which they provide information on.

**Table 2 Tree nut supply data**

<table>
<thead>
<tr>
<th>Tree Nuts</th>
<th>Global kernel supply</th>
<th>annual supply growth 2004-2013</th>
<th>Indian kernel demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Main Origin</td>
<td>in tonnes 2011</td>
<td>Min %</td>
</tr>
<tr>
<td>Cashew</td>
<td>India</td>
<td>569,262</td>
<td>-10</td>
</tr>
<tr>
<td>Almond</td>
<td>USA</td>
<td>901,200</td>
<td>-8</td>
</tr>
<tr>
<td>Walnut</td>
<td>China, USA</td>
<td>734,580</td>
<td>3</td>
</tr>
<tr>
<td>Pistachio</td>
<td>Iran, USA</td>
<td>360,738</td>
<td>-31</td>
</tr>
</tbody>
</table>

Table 2 shows that the worldwide kernel supply of the tree nuts is between 300,000 and 1,000,000 tonnes. Thereby supply has a similar magnitude. Further note that the USA is a major supplier of three out of four, except cashew, which accounts for 68% of USA tree nut imports (Phipps 2010). USA producer boards provide a lot of information to increase transparency in different tree nut sectors. The annual supply growth rates suggest that the pistachio industry has to cope most with supply fluctuations. Walnut is relatively stable. Interestingly in the USA pistachios and almonds are grown in large plantations compared to cashew farmers (Yadav 2010), which is suspected to have a curtail impact on supply volatility. The claim is not necessarily confirmed by Figure A6 in the Appendix, which shows Iranian supply from smallholders and US supply. One final conclusion can be drawn. The average supply growth for cashew, described in section 2.1.1 is lower than the growth rate of the other nuts. Cashew supply is growing the least of the nut markets.

India is still a net exporter for different nuts, despite small production quantities relative to major suppliers. In 2012-2013 India produced about 37,000 tonnes of in shell walnuts, while they consumed 22,000 (USDA 2013), i.e. 12100 tonnes of kernels. Production is located in the North of India with certain geographical proximity to Delhi and the major grower China (map, Figure 4). Almonds are the second most consumed tree nut, but India only supplies marginal quantities around 1000 tonnes per year. Overall US agriculture exports to India are worth 691 million US dollar in 2009, out of which tree nuts are the largest share with 190 million (Mathew et al., 2011, p.162). This makes

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\(^{8}\) Most updated figure retrieved on cashew refers to the consumption in 2009-2010
India the 4th largest almond importer for the US (ABC 2012). Therefore almond is the major import commodity for Indian-US trade. This trade is predominantly carried out on an in shell basis, while 68% of the US almond exports are shelled (ABC 2012). Conclusively India utilizes shelling capacity within their tree nut industry. Lastly India’s pistachios derive from Afghanistan and Iran, due to geographical proximity and free trade agreements (Mathew et al., 2011, p.158). All of the tree nuts are traded amongst others in Delhi, India.

2.2.2. Raw production and processing
Table 3 summarizes some production features of the concerned tree nuts. All the production features depend on genotypes, climate and other factors, which are only approximated. Features are connected to the main production area of each nut. The basic features compared are time to fruit bearing, the months of harvest, the yield and the different markets for grades, i.e. shelled and/or in shell consumer market. The sources are collated to the column which they provide information on.

<table>
<thead>
<tr>
<th>Tree Nuts</th>
<th>Main Origin</th>
<th>years to first fruit bearing</th>
<th>Seasonality</th>
<th>Yield (kernel nut ratio)</th>
<th>Grading markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashew</td>
<td>India</td>
<td>3 to 4</td>
<td>February to July</td>
<td>24%</td>
<td>shelled</td>
</tr>
<tr>
<td>Almond</td>
<td>USA</td>
<td>3 to 4</td>
<td>August and October</td>
<td>60% -65%</td>
<td>shelled</td>
</tr>
<tr>
<td>Walnut</td>
<td>China, USA</td>
<td>2 to 3</td>
<td>August to November</td>
<td>55%</td>
<td>shelled, in shell</td>
</tr>
<tr>
<td>Pistachio</td>
<td>Iran, USA</td>
<td>5 to 7</td>
<td>August to early October</td>
<td>54-59%</td>
<td>shelled, in shell</td>
</tr>
</tbody>
</table>

Major raw production quantities of cashew derive in the first half of the year contrary to the other nuts. Accordingly prices for raw materials are determined in different time periods. The years until a tree bears fruit are an issue for all four crops. Especially pistachio requires long tree growing phases until the first harvest year. While the other trees reach their full bearing capacity approximately after 6 to 8 years (Ravai 1995; ABC 2013; DCCD 2012), pistachio trees need 15 to 16 years according to American Pistachio Growers association (APG 2013) and 15 to 20 according to Iranian Pistachio Association (IPA 2013). Conclusively supply adjustments require long growing phases, particularly for the pistachio industry. Recall from table 2 that this industry also exhibits the most supply fluctuations. In order to receive the kernel the nut needs to be dried and processed. Note that the yield of the kernel varies greater over trees than shown in Table 3. The data’s yields are based on certain reference genotypes in distinguished areas. After shelling the nuts the output is graded. E.g. walnuts are graded into two distinctive markets, in shell and shelled. Walnuts for the shelled market are mechanically cracked. Then kernels are screened into a series of sizes, also quarters and broken grades, and checked through electronic colour graders (WBC, 2013). The USDA has formulated clear standards how to grade American tree nuts, e.g. walnuts (USDA-walnut-standards 1997). These grades differ by appearance, i.e. broken or wholes and colour attributes. On the contrary almonds have no in shell consumer market and therefore only shelled grades are advertised. The same holds true for cashew. In the USA almonds are mechanically harvested and processed and then graded according to USDA grades. The grades include broken types and are available on the homepage of the Almond Board California (ABC 2013). Pistachios are different to cashew and almond. They do have an in shell market, which is intended for snack consumption. In Iran in shell pistachios are
graded in 5 categories, none of the grades supplies explicitly broken nuts, rather limits the maximum defects in a package (IPA 2013). The whole grading is done to suit certain applications, e.g. the ingredient use.

2.2.3. Post processing
In shell nuts for the retail are roasted and then positioned as a snack, e.g. pistachios (IPA 2013). Consumption wise the in shell pistachio relates better to whole cashews than the shelled ones, as both are positioned as snack. In contrast to cashews pistachio kernels are not usually marketed as a snack, but as a food ingredient. Buyers of this ingredient product look for suppliers who remove shell pieces and other foreign material to a very high degree (IPA 2013). In general the nut industries have to stress impurity in packaged grades to provide maximum product security. It further follows from the quotation that consumption wise pistachio kernels compare better to lower cashew grades, e.g. broken nuts, which can be used as food ingredient. The quotation also states some uses within the 7 segments (section 2.1.4.2) for cashew as ingredient. Recall that secondary uses of cashew are still under development (section 2.1.4.2).

On the contrary almonds have always been used as an ingredient (Mathew et al., 2011, p.134). Similar to the other nut boards ABC promotes almond in different recipes. ABC promotes transparency and provides monthly updates for shipments, production expectations, etc. on their webpage. The board has expenses beyond 50 million US dollar per year to develop the industry\(^9\). After grading the almond are available in sliced, slivered and whole form to fulfil different application requirements. Almonds are roasted or flavoured in snack application, but are also applied as ingredient in chocolate, confectionary items, energy bars, bakery items, input for in savoury dishes, cereal, salad topping and desserts (ABC 2013). Theoretically these applications also present potential markets for broken cashews.

3. Data and Methodology

This chapter aims to provide transparency on the modelling carried out and the data applied. It explains the approach in data collection and introduces the final variables applied in this research (section 3.1). The econometric analysis (section 3.2) explains the approach to tackle both research questions.

3.1. Data management and description

Section 3.1.1 gives excellent information in regard to data management steps. Data management steps are displayed in Figure 5. The research variables can be overviewed in Table 4. Section 3.1.2 describes the variables with graphs, a Boxplot and a correlation table.

3.1.1. Data Management

To answer the research questions reliable price data for cashew kernels of different grades and other tree nut kernel prices is required. The data was collected in cooperation with the African Cashew Initiative (ACI). The data collection is structured and guided by the following data management model, which resembles and has been derived from the DESAP model, Using Self-Assessments for Data Quality Management – DESAP (Bergdahl et al., 2007, p. 90-91).

**Figure 5 Data management model**

![Data management model](source: abstracted from Bergdahl et al., 2007)

The main source used is Cashew-Info. It is a weekly bulletin with customers all over the world, including ACI. It provides market data, which reduces the information spreads and increases transparency in the sector. Besides the bulletins Cashew-info sells daily price data from Indian markets and handbooks on cashew for 2002, 2008 and 2011. Foretell Business Solutions Private Limited owns Cashew-Info and considers itself the most authentic information and research base on cashew with a large variety of human resources (Cashew-Info-web, 2013). The current bulletin is sold since 2002 and continues to be marketed successfully. For currency transformation the Bank of Canada’s database is chosen, merely due to their practical arrangements of currency data, which was much appreciated during data collection.

Table 4 explains the scheme used to check availability, structure and practical features of the data. It presents selected variables and the names applied to them. In the first step the scheme shows the classification of each variable, and then states the location of the observation, followed by observation duration, frequency and unit. The latter features have been different from source to source or location to location, but detailed exchange rates and calculated averages ensure a valid synchronization of the data.
Table 4 Research variables overview

<table>
<thead>
<tr>
<th>Rubric</th>
<th>Variable</th>
<th>Location</th>
<th>Duration</th>
<th>Frequency</th>
<th>Unit</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashew kernels</td>
<td>WW320</td>
<td>Cochin, Tuticorin</td>
<td>2002-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>wholes-cochin</td>
</tr>
<tr>
<td>Cashew</td>
<td>LWP</td>
<td>Cochin, Tuticorin</td>
<td>2003-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>brokens</td>
</tr>
<tr>
<td>Cashew</td>
<td>WW320</td>
<td>Delhi</td>
<td>06/2003-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>wholes-delhi</td>
</tr>
<tr>
<td>Cashew</td>
<td>WW240</td>
<td>Cochin, Tuticorin</td>
<td>06/2011-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>premiums</td>
</tr>
<tr>
<td>Other tree</td>
<td>Pistachio</td>
<td>Dehli</td>
<td>06/2003-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>pistachio</td>
</tr>
<tr>
<td>nut kernels</td>
<td>Irani</td>
<td>Dehli</td>
<td>06/2003-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cal. Almond</td>
<td>Dehli</td>
<td>06/2003-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>almond</td>
</tr>
<tr>
<td></td>
<td>Walnut</td>
<td>Dehli</td>
<td>06/2003-11/2012</td>
<td>monthly</td>
<td>$/kg</td>
<td>walnut</td>
</tr>
</tbody>
</table>

Source: (Cashew-Info 2004-2012)

The names for the common cashew grades are simplified to their general class of grade according to Table 1. Thereby wholes refer to WW320 and brokens to LWP. WW240 cashews are named premiums. The choice of variables is based on most representative locations in the markets. The market overview (chapter 2) has provided insights on locations in regard to the Indian and global cashew industry. The variables for the cashew kernel grades have been chosen on a FOB basis (section 2.1.2) at port. The location is Cochin/Tuticorin, because at these ports the quantities from different origins, i.e. Kerala, Tamil Nadu, Andrah Pradesh etc. (Figure 4) are aggregated. An estimation of the FOB prices captures the cashew market best. Samson Trading is one of the important sources for Cashew-Info to estimate prices at these ports. The analysis of tree nut prices, namely California almond kernels, pistachios Irani, walnut kernels and whole cashew kernels are gathered from the Delhi market. The other tree nuts are predominantly grown in northern regions in India or imported (section 2.2). The longest common duration for most of the variables is achieved from June 2003 until November 2012, which becomes the temporal scope of this research. Premiums are not included in the main econometric analysis. Thereby 6 variables (section 3.2) are analysed with 114 observations, except brokens lack 4 observations in 05/2009 to 06/2009 and in 06/2011 to 07/2011. Variables from different sources or different locations are not mixed. Cashew-Info bulletin prices are given on a weekly basis and monthly within the cashew handbooks. In order to synchronize, the averages from weekly available data have been aggregated to monthly values.

3.1.2. Data description
The final data is best overviewed in graphs. Figure 6 shows the price development of variables in Cochin/Tuticorin. The prices are given in US dollars per kg. It should be noted that monthly aggregation has smoothed the price curve, while daily or weekly observation could emphasize the fluctuations even more. The tick marks are set for June each year.
Figure 6 suggests a strong correlation between cashew grades. Premiums are clearly more expensive than both other grades. The price gap between brokens and wholes is larger than between premiums and wholes. Further the graph shows that after the price peak in 2008 and 2011 the spread of brokens and wholes seems to increase. The econometric results will provide more insights on this price spread over the whole time period.

Figure 7 presents the development of prices of substitute nuts in Delhi in US dollar per kg. It shows that almonds have become the cheapest tree nut in India in the very recent years. Pistachio is the high priced nut. At a first glance almond prices also seem steady over time. On the contrary walnut and pistachio imply higher price fluctuations. Common trends or price pattern cannot be concluded from simply looking at the graphs. The econometric analysis follows.

Figure 8 shows a boxplot of the research variables. The maximum and minimum values of each variable are displayed in a straight line and the boxes mark the range for average plus and minus one standard deviation. The variables cover 114 observations from 06/2003 to 11/2012, except brokens have only 110 observations available.
Cashew prices are lower in Cochin/Tuticorin than Delhi. In Cochin/Tuticorin cashew prices are observed immediately after processing including transport costs to the ports, while in Delhi potentially higher transaction and transport cost have been included. This yields a nominal price difference only. Nominal cashew prices are generally comparably low in India. India is the main supplier of cashew, while pistachios and almonds are imported from different origins (section 2.2.1) under different tariff regimes. Based on standard deviations Figure 8 shows the highest volatility in pistachio and walnut prices, while almond has the lowest price fluctuation. This feature is discussed in chapter 5.

Correlations among all prices are shown in Table 5. Strong and significant correlations suggest similar variation pattern between two variables. Correlations with 99% significance level or higher are marked in bold numbers.

### Table 5 Correlation of prices

<table>
<thead>
<tr>
<th>Correlations</th>
<th>wholes-cochin</th>
<th>brokens</th>
<th>pistachio</th>
<th>almond</th>
<th>walnut</th>
<th>premiums</th>
</tr>
</thead>
<tbody>
<tr>
<td>wholes-cochin</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>brokens</td>
<td>0.8458</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pistachio</td>
<td>0.6319</td>
<td>0.3336</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>almond</td>
<td>0.0877</td>
<td>0.1144</td>
<td>0.1382</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>walnut</td>
<td>0.7974</td>
<td>0.6716</td>
<td>0.6534</td>
<td>0.2154</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>premiums</td>
<td>0.9797</td>
<td>0.8246</td>
<td>0.6483</td>
<td>0.0688</td>
<td>0.8442</td>
<td>1</td>
</tr>
<tr>
<td>wholes-delhi</td>
<td>0.9799</td>
<td>0.7986</td>
<td>0.6882</td>
<td>0.0861</td>
<td>0.8094</td>
<td>0.9753</td>
</tr>
</tbody>
</table>

Source: (Cashew-Info 2004-2012)

The data implies a promising correlation between wholes-delhi and other nuts with the exception of almonds. Delhi and Cochin/Tuticorin whole cashew prices correlate by 0.98, which emphasizes the geographical integration of the industry, despite nominal price differences. I assume the same geographical integration for broken grade prices in the different locations. The correlation between premiums and wholes is stronger than between between broken and wholes. Pistachio and walnut correlate with all cashew grades significantly. Almond shows no significant correlation with any price. At this point the results seem not discouraging for cross price substitution between cashew, pistachio and walnut.
3.2. Econometric analysis
The econometric analysis is structured by splitting the two research questions. The price spread analysis exploits the variables in Cochin/Tuticorin. The substitution model answers the second research question with the help of price variables from Delhi and the brokens series. The variables in equations are abbreviated:

a. \( P_{\text{whc}} \) = prices of wholes, Cochin (WW320)

b. \( P_{\text{whd}} \) = prices of wholes, Delhi (WW320)

c. \( P_{\text{br}} \) = prices of brokens (LWP)

d. \( P_{p} \) = prices of pistachio (Irani)

The software package “STATA 10” is used for the econometric analysis.

3.2.1. Price spread analysis
Broken grades can be seen as a by-product of whole cashews. Supply of both has a fixed relationship, influenced by processing features (section 2.1.2). Under the assumption that full mechanization spreads in the cashew sector, the relative supply of broken grades increases. In the industry it is discussed if cashew buyers (post processing) do compensate this additional supply by increasing the demand on broken cashews. Regardless of the application of broken grades the spread analysis is used to test for a trend in the price spread between both grade types. Explicitly this econometric model analyses the development of the spread of wholes-cochin and brokens from 06/2003 to 11/2012. An ordinary least square (OLS) model is considered with the spread \( (P_{\text{whc}} - P_{\text{br}}) \) regressed upon time.

\[
(1) P_{\text{whc}} - P_{\text{br}} = \alpha + \beta \cdot \text{time} + \varepsilon_t \quad \alpha, \beta \in \mathbb{R}
\]

The expression \( (\beta \cdot \text{time}) \) represents a trend over time, if the coefficient turns out to be significant. The error term \( \varepsilon_t \) should follow a white noise process to isolate a deterministic time trend and avoid a spurious regression. Before the spread is analysed, a structural break test is performed to prevent misspecification of residual based tests. However, first the missing values for brokens are interpolated.

Missing observations
It is assumed that no a priori information is available on the missing values. They are situated between available observations. Therefore the time series of brokens is interpolated with proxy values. These values are obtained by regressing the known values of brokens upon a set of supporting variables, here premiums and date of observation. Then the fitted values of this regression replace the unknown observations. Thereby the fitted values are estimated with the help of the development over time and the seasonality in premium prices. The estimates of equation 1 remain consistent as no a priori information suggests that the error term \( \varepsilon_t \) is correlated with the supporting variables, which would cause a measurement error. This procedure is referred to as “first order process” (Pindyck and Rubinfeld, 1998, p. 247).

Structural breaks and stationarity
After adding the fitted values the “spread \( (P_{\text{whc}} - P_{\text{br}}) \)” can be calculated for 114 observations, i.e. 06/2003 to 11/2012. Before estimating equation 1 structural breaks are accounted for. Structural breaks are an important source of misspecification. They can lead to low power of residual based tests as stated by Gregory and Hansen (Gregory and Hansen, 1996). Stationarity tests are residual
based. The variance and mean of a time Series variable is often not constant, due to a deterministic and/or stochastic trend. This phenomenon is called non-stationarity. The Zivot and Andrews procedure accounts for both structural breaks and non-stationarity. The null hypothesis states that a series is non-stationary, i.e. some trend in the spread, and without an endogenous structural break. The alternative hypothesis suggests a stationary series or an unknown structural break (Zivot and Andrews, 1992). The procedure is flexible. It requires no prior information on a structural break; it identifies potential breaks and assures or rejects a trend in the series. In case the procedure fails to reject the null hypothesis equation 1 is estimated with OLS, otherwise the break is identified and the steps are repeated for a series before and after the structural break.

**Confirmation of a deterministic trend**

Equation 1 attempts to estimate a linear deterministic time trend for the spread and especially the significance of such a trend. In equation 1 the subtracting of \( \alpha + \beta \times \text{time} \) would yield a stationary process for the price spread, if no stochastic trend is present. Conclusively \( \varepsilon_t \) follows a white noise process, i.e. stationary process. A common stochastic linear trend process is the “random walk model”, which suggests that the dependent variable is impacted by its lagged values. Caiado and Crato distinguish the trends concretely (Caiado and Crato, 2005). In case of a stochastic trend I cannot impose the assumption that a deterministic trend is responsible for an impact of time on the spread. Conclusively the error term \( (\varepsilon_t) \) of equation 1 is tested for stationarity. Here the Dickey-Fuller (DF) and KPSS test are applied. The null hypothesis of DF is non-stationarity, while the alternative hypothesis suggests stationarity. The opposite holds for the KPSS test (Kwiatkowski et al., 1992).

**3.2.2. Substitution model**

Let me first scroll back to chapter 2, which distinguishes the snack and ingredient market for cashews. Broken cashews and other tree nuts, e.g. almond or pistachio, are widely used as ingredient. The snack market prefers cashew wholes and quality grades of other tree nuts. Given the potential demand overlaps for both marketing types I test for substitution among the tree nuts in Delhi and the interpolated broken cashew series (see also Table 4). Substitution expresses itself in a long run relationship between prices. In the short run price shocks can disturb equilibrium prices. The transmission time can vary. I exclusively look for long run relationships. A long run relationship between two variables is found in the cointegration of two variables (Engle and Granger, 1987). Similarly Ogakia and Reinhart (Ogakia and Reinhart, 1998) accounted for substitution between durable and non-durable goods. If cointegration is found, then a vector error correction model (VECM) is constructed to explore dynamic relations among the variables. Before a test for cointegration some pre-conditions have to hold. In particular the price variables have to be of the same order of integration, different from zero.

**Order of Integration**

The transformation of a non-stationary variable can recover the property stationarity. These variables are transformed with first differences: \( \Delta Y_t = Y_t - Y_{t-1} \). If first differenced variables \( \Delta Y_t \) are found to be stationary, exclusively after transformation, then they are integrated at first order (Verbeek 2008, p.281). All previously introduced stationarity tests are applied to account for structural breaks and to ensure an accurate identification of stationarity. A trend is included in the tests to account for non stationarity due to a deterministic trend. The tests include DF, KPSS and the Zivot and Andrews procedure.
**Cointegration**

Cointegration can capture inter-commodity market linkages, here among tree nut prices. It occurs if two or more non-stationary series with the same order of integration, have the same stochastic trend in common (Verbeek 2008, p.328 and 338). Engle and Granger (Engle and Granger, 1987) define cointegration as two time series, each by itself is assumed to be non–stationary, while a linear combination of the two series, achieves stationarity. A potential linear combination of two variables is described in equation 2, which shows the linear combination for wholes-delhi and pistachio:

\[ p_{p,t} - \alpha - \beta p_{whd,t} = \varepsilon_t, \quad \alpha, \beta \in \mathbb{R} \]

If the error term \( \varepsilon_t \) is found to be stationary, then there exists a long run relationship among the variables. The parameter vector \((1, -\beta)\) is the co-integrating vector that removes the common trend. The Johansen’s maximum eigenvalue and trace test (Johansen 1991) allow for multiple cointegration relationships among a set of variables. The number of cointegrating relationships determines the rank of the set. If the rank is found to be zero, then no substitution between prices can be proven, otherwise a VECM model is constructed.

**VECM**

A VECM can collate cointegrating relationships to the involved variables, i.e. the results of the VECM indicate an answer on which cointegrating relationship(s) Johansen’s tests identified. Those relations are confirmed by steps described for equation 2. Further the VECM allows for an adjustment parameter (parameter vector, section 3.2.2) in a regression model. Such model can be used to estimate impulse response functions that indicate how a price reacts to a shock in another price (Verbeek 2008, p.338). In case of a single cointegrating relationship between pistachios and whole cashews the model would be specified:

\[ \Delta p_{p,t} = c + (1 - \pi)*\left( p_{p,t-1} - \alpha - \beta p_{whd,t-1} \right) + \gamma \Delta p_{p,t-1} + \delta \Delta p_{whd,t-1} + \varepsilon_t, \quad \alpha, \beta, \gamma, \pi \in \mathbb{R} \]

Where \( \Delta \) is the first difference operator; \((1 - \pi)\) is the parameter vector that measures the speed of adjustment at which deviations from long run equilibrium are corrected in the following period; the expression \( (p_{p,t-1} - \alpha - \beta p_{whd,t-1}) \) is the error correction term derived from equation (2); \( \delta \) and \( \gamma \) measure the short run elasticity of price transmission for the first lagged values; and \( \varepsilon_t \) is the error term which follows a white noise process, i.e. inter alia stationary. Now the model can be used to estimate long and short run relationships and the speed at which a market returns to an equilibrium after a price shock.
4. Results
The following chapter introduces the research results. The econometric results are illustrated in conform order to section 3.2 First section 4.1 reveals a significant time trend and additional conditions for time series. Then section 4.2 gives the findings for the orders of integration and the lack of cointegration among tree nut variables.

4.1. Price spread analysis
As discussed in section 3.2.1 the missing values of brokens are forecasted by premiums and time. Both are decent estimators, with highly significant parameters, yielding a combined regression-coefficient $R^2$ of 0.88 (Table A2 Appendix). The forecasted values fill the blank observations in the brokens series. The combination of the 4 additional values and the brokens series is called brokeninterpolated. The 4 additional values are displayed in Table A3 (Appendix). After forming the spread of wholes-cochin and brokeninterpolated the Zivot-Andrews procedure is applied on the spread. The null hypothesis states that a series is non-stationary, i.e. some trend in the spread, and without an endogenous structural break. The alternative hypothesis suggests stationarity or an unknown structural break in the series. The procedure yielded a test value of -3.166 in respect to a critical value of -4.42 at a 99% significance level. Conclusively the null hypothesis could not be rejected. The most likely structural break is announced for observation 97, i.e. 06/2011. Anyhow neither a structural break nor stationarity is found in the spread. So the spread is regressed upon time, according to equation 1 (section 3.2.1). The regression output is given in Table 6.

| Variables | Estimate | Std. Err. | $P>|t|$ |
|-----------|----------|-----------|--------|
| time      | 0.019    | 0.001     | 0.000  |
| intercept | 0.594    | 0.092     | 0.000  |
| No. of obs.| 114      | Prob > F  | 0.000  |
|           | R^2      | 0.614     | adj. R^2 | 0.610 |

The results confirm a positive time trend. Over the observation period of roughly 9 years the spread between wholes and brokens has increased by an average of 2 cents per kg every month. Note that all available observations are included. The observations are not limited to a specific time period, which is suspected to reflect such a trend. The additional DF and KPSS tests indicate stationarity of the residual at a 95 % significance level (Table A4 Appendix), which means the absence of a stochastic trend. Conclusively there was found a highly significant deterministic time trend (Table 6) for the spread, which proves that wholes and broken prices have been drifting apart. This preliminary result does not support the claim that buyers of cashew shift between broken and whole grades in order to achieve an equilibrium price between the grades. Such equilibrium is crucial for a clear substitution process between the grades. Further implications of these results are discussed in chapter 5.

4.2. Substitution model
The substitution model aims to identify long run relationships between cashew grades and other tree nuts. Variables with the same order of integration are potentially cointegrated (section 3.2.2), which is a strong reference of a substitution relationship. First the order of integration is identified as discussed in section 3.2.2. The brokens series remains represented by brokeninterpolated. Table 7 shows the test values of the applied stationarity test, namely DF, KPSS and Zivot-Andrew procedure. The DF test is run before all others to search for a deterministic trend in a series. If no deterministic trend is found in the series, then the critical values for stationarity differ. Therefore almond’s critical
values are additionally noted. The test is performed for the base levels and the first differences of a series. Decisions to reject a test hypothesis are based on critical values for a 95% significance level. The test values for the KPSS test refer to the lag order zero value. The Zivot & Andrews procedure is only performed for base level variables. The procedure additionally identifies structural breaks, if the null hypothesis is rejected. The test outcomes are shown in Table 7.

Table 7 Stationarity tests for wholes, brokens, pistachio, almond and walnut series

<table>
<thead>
<tr>
<th>Price variable</th>
<th>Price variable</th>
<th>DF</th>
<th>KPSS</th>
<th>Zivot-Andrews</th>
<th>Order of Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price variable</td>
<td>disciplines</td>
<td>-3.45</td>
<td>-2.89</td>
<td>0.146</td>
<td>0.463</td>
</tr>
<tr>
<td>Trend</td>
<td>Levels</td>
<td>-2.64</td>
<td>-3.613</td>
<td>0.752</td>
<td>0.0823</td>
</tr>
<tr>
<td>Levels</td>
<td>Levels</td>
<td>-2.953</td>
<td>-3.077</td>
<td>0.471</td>
<td>0.171</td>
</tr>
<tr>
<td>Levels</td>
<td>Levels</td>
<td>-3.025</td>
<td>-2.301</td>
<td>1.05</td>
<td>0.16</td>
</tr>
<tr>
<td>Levels</td>
<td>Levels</td>
<td>-2.547</td>
<td>-4.267</td>
<td>0.257</td>
<td>0.07</td>
</tr>
<tr>
<td>Levels</td>
<td>Levels</td>
<td>-2.89</td>
<td>-1.95</td>
<td>0.463</td>
<td>-4.8</td>
</tr>
<tr>
<td>Trend</td>
<td>Levels</td>
<td>-2.691</td>
<td>-3.06</td>
<td>0.883</td>
<td>0.183</td>
</tr>
<tr>
<td>Levels</td>
<td>Levels</td>
<td>-3.546</td>
<td>feb-05</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

All three tests agree that all level series are non-stationary. DF and Zivot-Andrews test cannot reject the null hypothesis of non-stationarity and KPSS rejects the null hypothesis of stationarity. No structural break is concluded from Zivot-Andrews test set up (section 3.2). The first differences lead to stationary variables except Pistachio. For the other variables the first order of Integration is concluded. Pistachio's results are controversial. DF test sometimes lacks power to reject the null hypothesis, while KPSS might accept a false null hypothesis. Anyhow KPSS indicates a first order of integration series, while DF assumes a higher order. Supplementary tests are carried out in case of a cointegrating relationship of pistachio and another variable. The order of integration results are summarized in Table 7. If these variables of first order integration have the same stochastic trend in common, then a cointegrating relationship between them can be identified. Therefore the Johansen maximum eigenvalue test and trace test (section 3.2.2) are carried out. The test identifies the rank, i.e. the number of cointegrating relationships among the set of variables. All five variables in Table 7 are included in the test. The null hypothesis states the rank tested for. If the test statistic is not larger than the critical value, then the currently tested rank is equal or smaller than the real rank of the variable system. Table 8 displays the results.

Table 8 Johansen rank tests for wholes, brokens, pistachio, almond and walnut series

<table>
<thead>
<tr>
<th>Maximum rank</th>
<th>Sample</th>
<th>4-114</th>
<th>Lags</th>
<th>3</th>
<th>No. of obs.</th>
<th>111</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>eigenvalue</td>
<td>trace statistic</td>
<td>95% critical value</td>
<td>max statistic</td>
<td>95% critical value</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>49.688*</td>
<td>68.52</td>
<td>21.8014*</td>
<td>33.46</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.17832</td>
<td>27.886</td>
<td>47.32</td>
<td>12.5314</td>
<td>27.07</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.10676</td>
<td>15.355</td>
<td>29.68</td>
<td>8.6813</td>
<td>20.97</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0752</td>
<td>6.673</td>
<td>15.41</td>
<td>6.567</td>
<td>14.67</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0574</td>
<td>0.106</td>
<td>3.76</td>
<td>0.106</td>
<td>3.76</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.00096</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20
Both tests cannot reject the null hypothesis for maximal rank 0, which is additionally marked by a star in Table 8. Thereby no cointegration as described in equation 2 (section 3.2.2) is found. Without cointegration it is not possible to construct a VECM to estimate adjustment parameter and long run equilibriums. Therefore the econometric analysis has to be stopped at this point. No cointegration between all five variables is concluded. This means the price data holds no evidence for substitution. The results imply no substitution between cashew grades and other tree nut kernels. Additionally they imply no substitution between other tree nuts or between the cashew grades. Chapter 5 discusses likely reasons and background information in this regard.
5. Discussion and Conclusions

This chapter discusses the results and methodology of this research. Section 5.1 points out the implication of the results for the market actors in the cashew sector, in particular processors. Section 5.2 ensures an accurate interpretation of the research results in the methodological framework.

5.1. Results

This section reflects on the research results. Two research questions have guided this research. One, what is the price development of broken cashews relative to whole cashews? Two, are cashew grades substituted by almonds, pistachios or walnuts? The analysis has revealed a significant upward trend in the spread of broken and whole cashew grades and the absence of a long run relationship between any tree nuts. Section 3.1.2 has illustrated the research variables to answer these questions. Chapter 2 has introduced the value chain of tree nuts in particular cashew. This information supports the discussion of both findings.

5.1.1. An increasing price spread between whole and broken cashew grades

For a better understanding of broken and whole cashew prices, section 2.1.2 is recalled. The breakage percentage of nuts is a processing feature with economic importance (Table 1). The results prove clearly that the price difference of wholes and broken grades has significantly increased since 2003. The spread reached a historic high, at least since 2003. Figure 6 shows how the spread increases more rapidly after the price peaked in 2008 and 2011. On the one hand there is supply. Mechanization has enlarged the broken percentage in batches relative to manual shelling (section 2.1.2). This has increased the supply of broken and decreased the supply of whole cashews. Improvements on the shelling technology would boost the economic feasibility of fully mechanized cashew processing. Otherwise manual shelling like in India might regain importance worldwide.

Some industry actors are well aware of grade distortion in cashew supply. A bulletin on cashews, “Cashew Club” (Fitzpatrick 2012), states that cashew pieces continue to be oversupplied in particular in Vietnam, which is the biggest kernel exporter (section 2.1.2). This produces selling pressure for processors. Conclusively the bulletin summarizes that the market for pieces has not been as developed as for wholes (Fitzpatrick 2012). On the other hand there is demand. Section 2.1.3 explains how broken grades are used as ingredient in different food value chains. It further explains that this use is limited to India. The results clearly show that the usage is not sufficient to keep a steady price spread between whole and broken grades. Vietnamese processors have high selling pressure, as they have to cope with a 30% import tariff for cashew in India. However selling pressure for pieces is not limited to Vietnamese processors. African and other international processors should have an interest in developing a demand on pieces. Intuitively three solutions are feasible. One, a tax reduction in India would increase the import demand for pieces; two, broken grades gain more acceptance on the snack market; three, the international market has to develop cashew as ingredient, following the example of India. The first solution depends on the regulatory framework in India. Indian processors have a strong economic interest in maintaining the import duty and will lobby against such measures. The second solution will not be discussed in this study, because no information was collected on consumer behaviour. The third option is still problematic for various reasons. Historically in many ingredient segments (section 2.1.3) almonds and hazelnuts are more common ingredients, especially in the EU and USA, which are the major importers of the market (Figure A3 Appendix). Bakeries, confectionary items, savouries and chocolate items are hardly upgraded with the use of cashew. Theoretically cashew can replace other tree nuts, e.g. Kraft Foods
owns Cadbury India which does produce chocolate filled with caramelized cashew. However the demand problem is not purely related to wholesalers and other kernel buyers. Processors can also do a great deal to promote broken grades as ingredient. The cashew handbook has structured helpful pre-conditions in different categories (Mathew et al., 2011, p.135-136):

1. Standardization: improve homogeneity of processing outputs, e.g. establish impurity limits
2. Consolidation: increase trade contacts in a more transparent market, so that buyers can source from a larger amount of processors
3. Distribution: decrease logistic bottlenecks, delays and defaults
4. Promotion: positive aspects of cashew deserve more attention in marketing, e.g. taste or nutritional benefits; here a great deal can be learned from ABC, which has a decent budget to market almonds worldwide (section 2.2.3).

Standards and quality issues, consolidation and distributions are long known issues of the cashew supply chain. Ruben et al. (2007, p.235) confirms these issues for the supply chain of Kerala kernels (Figure 2). The implementation of the handbook’s pre-conditions can support a buyer friendly environment. These efforts increase the awareness for the price gap between grades throughout the whole value chain, including the retailers. Not just Vietnam, but processors in Africa and all other cashew producing countries (section 2.1.1) could market their broken grades more effectively.

Conclusively broken and whole cashew grades are related in supply, while their demand is very differently developed. This has caused a price gap which becomes increasingly economical relevant, because broken grades become relatively cheaper every month. One option would be to develop international demand for broken grades. This requires the implementation of pre-conditions discussed in this section. An initiative by wholesalers, retailers and especially processors could improve the current stage of broken grade’s demand.

5.1.2. The absence of substitution between cashews and other tree nuts
The results (section 4.2.2) do not provide evidence for the substitution of whole nor broken cashews with other nuts. The study results are focused on substitution of these grades by pistachio, almond or walnut. However prices depend on a variety of supply and demand factors besides demand substitution.

Section 2.2 explains overlaps and differences in regard to supply and demand of the commodities. The magnitudes of supply resemble each other. No commodity supplies more than a million tonnes of kernels annually. Given the market magnitude demand substitution between commodities would affect the involved industries. Nevertheless, cashew supply derives in another season than the other commodities (Table 3). Therefore it seems less likely that the raw prices are compared to other tree nut prices. All tree nuts are rather supply inelastic. The crop is not grown yearly, but the trees need time to achieve full bearing after a minimum of six years. Processors have to adjust to available raw material of tree nuts. Based on Table 2 pistachio has the most supply volatility and almonds reveal the lowest. The same holds for the volatility ranking in commodity prices based on Figure 8. Another study argues that “almonds and pistachios are grown in very large plantations in the US and thus their prices are steady year after year” (Azam-Ali and Judge, 2001, p. 7). This is confirmed for almonds, but clearly rejected for pistachios. On the one hand a substantial amount of pistachios is grown by smallholders in Iran (Figure A4 Appendix). On the other hand Pistachio supply is supposedly the most inelastic among the commodities, given the long time frame until first fruit bearing of new
trees (Table 3). Therefore supply is volatile (Table 2) and might cause the price volatility observed in this research (Figure 8). Based on the discussed supply factors (section 2.2) cashew and walnut are the most comparable markets. Their prices indeed show the highest correlations between nuts (Table 5). However no long run relationship can be confirmed. No demand overlap of the commodities has been identified in this study. Additionally in the last year of observation Figure 7 indicates no common developments for the two commodities. Therefore price correlations might be limited to a similar supply phase without direct relations of both supply chains.

Prices are largely driven by demand, amongst others due to inelastic supply. Consumers purchase tree nuts in snack form or as an ingredient in other food product. Historically almond and pistachio are widely used as ingredient (section 2.2.3), while the cashew processors struggle to do so outside India (section 5.1.1). The results confirm the spread analysis. Shifts between broken and whole cashews, i.e. shifts between snack and ingredient application, are rarely price driven. Products with tree nut ingredients favour cheaper grades, but cashew processors were not able to implement broken grades in such use. Potentially impurity issues or a lack of marketing have constrained distribution. Compared to almonds cashew has barely a marketing board. An association that positions broken cashews as ingredient with its favourable features would be beneficial for the whole industry. In India KSCDC could fulfil such task. Nevertheless ABC is an association, whose experiences can guide such a cooperation. Maybe this can lead to an adjustment of food product recipes in favour of cashew. However, today cashew is predominantly consumed in snack form. This snack, i.e. WW320 price, shares no long run relationship with any tested tree nut. No research is known to the author that has addressed substitution between tree nuts before. The cashew handbook (Mathew et al., 2011, p.138-139) has calculated cross price elasticities, which are carried out under the assumption of substitution. The results indicate that pistachio and cashew have a positive cross price elasticity over the period 2001 to 2010, which means they are economic substitutes. On the other hand almond and cashew have even a negative cross price elasticity from 2003 to 2010, which would make them complementary goods. Along the value chain (chapter 2) there is hardly evidence for a complementary relationship between tree nuts. Solely the marketing of a mix of nuts (section 2.1.3) can support such claim. But especially a mix of nuts provides the opportunity for wholesalers to change nut shares in the mix based on current prices. This would be a substitution process. Also the consumer market of nuts allows for substitution. All of these tree nuts are available in numerous (super)markets worldwide. However the research result can find no evidence for the assumption of substitution. The author assumes that the impact is insignificant in comparison to other price driving factors. It is advisable for market actors to be aware of more significant price drivers.

To sum up, the pricing of the cashew depends on a variety of supply and demand factors. Supply relates to other tree nuts in terms of magnitude. On the contrary outside India other tree nuts, especially almonds, are more effectively positioned as food ingredient. On the snack market wholesalers can change the percentage of nuts in a nut mix. Additionally final consumers can shift between the pure tree nut packages. These potential impacts have not been sufficient to find economic substitution (chapter 1) between the nuts. Comparable commodity prices are not a significant price factor.
5.2. Reflection on Methodology

In the econometric analysis a simple OLS model was applied, while additional tests accounted for time series properties to avoid a spurious regression. The series for broken cashews has been interpolated to add missing values. The procedure applied has yielded highly significant estimators (Table A2 Appendix). This supports the expectation of an accurate value estimation. The resulting trend between whole and broken grades cannot be denied from a methodological point of view.

The methodology of the substitution model can mislead the reader. Some studies like (Goodwin and Schroeder, 1991) apply cointegration to identify spatial market linkages within the same commodity. Studies like (Ogakia and Reinhart 1998) or (Narayan and Narayan, 2005) also applied cointegration in order to account for price substitution, but supply data was integrated in these studies. In this research supply data was not available on a monthly basis, i.e. in the same frequency as prices. Additionally annual data varies from source to source. E.g. India's production level in 2010 was estimated at 465,000 (Fitzpatrick 2011) and 613,000 (ACA 2012) tonnes. Those reasons have caused the negligence of supply quantities within the econometric analysis. Nevertheless prices are partly driven by supply quantities. Also supply data on transaction cost structure, import duties, cost of processing, currency exchange rates, freight and distribution costs impacts the price (Mathew et al., 2011). In case substitution elasticities between the tree nuts are low, empirical data might not be able to trace an existing relationship between prices. Other supply and demand features, like supply volumes, are too dominant for price developments compared to competitor prices.

Other drawbacks on the substitution model have been that only one price on each alternative tree nut was retrieved and that the broken series derived from a different location than other prices. In regard to inter regional price differences the variance in different locations has been identified as highly correlated. Wholes in Delhi and Cochin/Tuticorin correlate by over 0.97. Hence an absolute conformity in regard to locations is unlikely to alter the research conclusions. Similarly the correlation between cashew grades has been above 0.97, with the exception of the broken grade. Chapter 2 revealed one major difference in this regard. Broken grades are intended for the use as ingredient, while whole grades supply the snack market. Demand differs between those grade types. Therefore a broken or whole grade might be involved in substitution with the alternative tree nut kernels. Nevertheless the research could gain explanatory power by integrating the grading structure of other tree nut commodities. This would yield the marketing position of different grades within one commodity.

The alternative tree-nut commodities have been limited to pistachios, almonds and walnuts. Recall from section 2.3 that cashews are marketed as ingredient or snack. Within these rubrics comparable products are all tree nuts, but also peanuts are very plausible competitors. On the snack market even more competitors are plausible, e.g. potato chips. Price substitution might be linked to other products than discussed or is even spread over a whole variety of competitors.

Lastly not all factors of the supply chain are captured in this research. E.g. time gaps within the supply chain make it difficult for buyers to shifts between nuts based on price. Traders generally purchase from raw nut processors on a forward basis, often between 6 month and one year. Conclusively traders are not overly flexible and the demand-price relation is distorted. This could be a key element to further explain the findings of no substitution.
Summarized further research could address tree nut substitution focusing on the value chain of food products with cashew as ingredient. Also a cashew value chain should include inter-temporal measures. Both analyses can yield hazards in regard to cashew consumption. Further grades of other tree nuts do supply different applications of their buyers. Besides grades other commodities, like peanuts, are potential substitutes for cashew. An analysis can reveal more suitable competitor prices for each cashew grade.
References


Appendix

Figure A1 Global RCN supply

Global RCN supply

Source: (ACA 2012)

Figure A2 Cashew nut processing scheme

Source (Azam-Ali 2002)
Figure A3 Global kernel imports by country

Global Kernel Imports

Source: (FAO 2012) (see also CashewInfo Volume 13, Issue 29)

Figure A4 Shelled almond supply and consumption

Almond Supply and demand

Source: (USDA 2013)
Figure A5 In shell walnut supply and consumption

![Walnut Demand and Supply](image)

Source: USDA 2013

Figure A6 In shell Pistachio supply and consumption

![Pistachio Supply and Demand](image)

Source: USDA 2013
Table A1 Processing units, Capacity and Utilization in India 2005-2006

<table>
<thead>
<tr>
<th>States</th>
<th>Processing Units (No.)</th>
<th>Capacity (1000 t)</th>
<th>Utilization (1000 t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indigenous</td>
<td>Import</td>
<td>Total</td>
</tr>
<tr>
<td>Kerala</td>
<td>432</td>
<td>600</td>
<td>67</td>
</tr>
<tr>
<td>Karnataka</td>
<td>266</td>
<td>300</td>
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</tr>
<tr>
<td>Goa</td>
<td>45</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>Maharashtra*</td>
<td>350</td>
<td>50</td>
<td>20</td>
</tr>
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<td>Tamil Nadu</td>
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</tr>
<tr>
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</tr>
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<td>Orissa</td>
<td>209</td>
<td>100</td>
<td>11</td>
</tr>
<tr>
<td>West Bengal</td>
<td>30</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Chattisgarh</td>
<td>3</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td>NE States</td>
<td>22</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>3799</td>
<td>1623</td>
<td>573</td>
</tr>
</tbody>
</table>

Source: (DCCD)

Table A2 Regression broken upon time and premiums

| Coefficients | Estimate | Std. Err. | P>|t| |
|--------------|----------|-----------|-----|
| time         | -0.033   | 0.002     | 0.000 |
| premiums     | 1.280    | 0.054     | 0.000 |
| intercept    | -2.377   | 0.248     | 0.000 |

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<tr>
<th>No. of obs.</th>
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<th>Prob &gt; F</th>
<th>R²</th>
<th>adj. R²</th>
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<tr>
<td></td>
<td>0.000</td>
<td>0.879</td>
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</tbody>
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Table A3 Interpolated values for broken cashews

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<thead>
<tr>
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<th>broken</th>
<th>Interpolated</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-04</td>
<td>2.78</td>
<td></td>
</tr>
<tr>
<td>2009-05</td>
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<tr>
<td>2009-06</td>
<td>3.23</td>
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<td></td>
<td>...</td>
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<td>7.28</td>
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<td>2011-06</td>
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<tr>
<td>2011-08</td>
<td>8.65</td>
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Table A4 DF and KPSS test on residuals of equation 1

<table>
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<th>KPSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>critical values 95%</td>
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</tr>
<tr>
<td>residuals test value</td>
<td>-3.792</td>
</tr>
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