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Potato Prices as Affected by Supply and Demand Factors: An Irish Case Study

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Abstract

The supply and demand factors affecting the farm level price for Irish potatoes has undergone considerable change in the last two decades. On the demand side, per capita consumption has decreased by almost a half, and the use of potatoes has shifted from consumption of table stock potatoes towards greater levels of processed potato products. On the supply side, domestic production levels of potatoes decreased by just over 30 percent, whilst grower numbers decreased by greater than 75 percent over the same period. Against this background of significant changes in domestic consumption levels and patterns and domestic production of potatoes this paper examines the effect of these factors on potato price levels and variability.
Farm level price and volatility is a concern for a number of reasons as it adds challenges for business planning, debt repayment, and, in some cases, solvency. Farm level price data and supply and use balance sheet data from Eurosta are used in an ARCH modelling framework to quantify and examine the factors affecting potato price mean levels and volatility.

Keywords: Price volatility, ARCH, potatoes

JEL classification:.

1. INTRODUCTION

In agricultural markets, where prices are not supported through coupled price support policies, prices tend to adjust in response to changes in production. Whilst most agricultural markets in the European Union are still highly regulated by the Common Agricultural Policy, no direct interventions are applied to the potato market. In addition economic theory suggests the price inelastic nature of agricultural commodity supply and demand means that the prices associated with such commodities may be subject to sudden and relatively large price adjustments. This characteristic of the potato market in particular is amplified by the fact that fresh potatoes are perishable products with nearly no carryover stocks between seasons. Hence relatively small changes to supply or demand often lead to relatively large price fluctuations.

Given that farm level price and volatility is a concern for a number of reasons as it adds challenges for business planning, debt repayment, and, in some cases, solvency, it is important to understand the factors driving price formation and volatility. Hence, the objective of this paper is to look at the relationship between Irish potato prices and the factors that might affect its mean value and volatility over time.

Given the nature of product and the associated non constant price variance we can expect to be associated with it, the modelling of potato price levels and variance is not suitable in the general ARIMA (AutoRegressive Integrated Moving Average) framework. Prices which display time

varying level of variance are better modeled as ARCH (AutoRegressive Conditional Heteroskedasticity) processes.

This paper commences with an overview of the Irish potato industry. Secondly an outline of the models and methodology employed to quantify the factors affecting price formation and volatility in the Irish potato market outlined. Finally these results are presented and discussed and some conclusions drawn before avenues for further research are considered.

2. OVERVIEW OF THE IRISH POTATO SECTOR

This section of the paper will review the size of the sector at farm gate, importance in an EU and Irish context in agricultural terms, consumption trends and supply chain management issues associated with the sector.

2.1. Supply Factors ~ Area, Production and Value in an Irish and EU context

The potato sector in Ireland is relatively small by EU standards representing about 1% of EU production of 45 million tonnes (EU Commission, 2010). Apart from starch potatoes grown in mainland Europe, there is no Common Organisation of the Market compared to most of the other tillage sectors such as cereals, protein crops, oilseeds, sugar beet, etc. where subsidies and/or market supports are in operation.

Prior to Ireland entering the EU over one million tonnes of potatoes were produced on an annual basis compared to 420, 000 tonnes in 2010. In the last two decades (1990- 2010) the production area has halved with producer exit from the sector accelerated by market forces and alternative farming options within the supported CAP. While area of production has decreased in Ireland over the recent past, productivity has increased in the period, due mainly to improved varieties and agronomic factors, the overall volume of potatoes has fallen by about 30 percent in the past two decades (Figure 1).

Figure 1 Area and Production of Potatoes in Ireland (1990 – 2010)
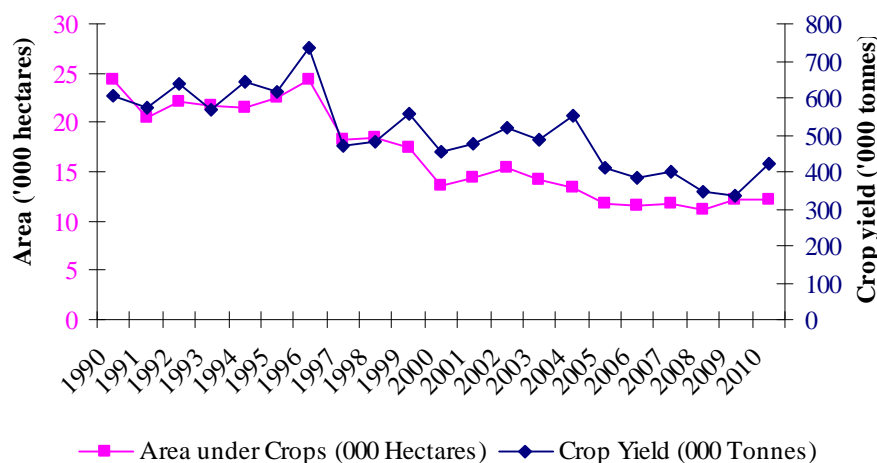
Source: CSO, various years

While there has been a decline in overall European production over the past two decades, of a similar magnitude to that experienced in Ireland, the reduction is not as marked in the UK or The Netherlands, countries which Ireland has traditionally competed with on export markets. The fall in the UK area was about 22 percent during the period 1990 to 2010, while yield increases over the same period did compensate to some extent, overall production levels did decline by 6 percent over the period. Production area in the Netherlands declined by 10 percent and production volume declined by a mere 3 percent in the period under review.

Data on the total potato production in the EU-27 and selected countries is presented in Table 1 for the period 2001 – 2010. .In particular, the EU-5 zone comprising UK, the Netherlands, Belgium, Germany and France, are identified in this Table, as they are considered as the most efficient and integrated area in the EU's potato busyness sector (EU Commission, 2010).

Table: Production of Potatoes (EU Selected Counties, 2010, change since 2001)

|	2010 Production Volume	% change '01/'10
Belgium	3455800	1.35
France	6582190	1.08
Germany	10201900	0.86
Ireland	330500	0.69
Netherlands	6843530	0.96
United Kingdom	6045000	0.91
EU-5 total	33128420	0.97
Europe + (Total)	107473229	0.78

Source: FAOSTAT, various years

2.2. Demand Factors~ Consumption Trends

World demand for potatoes is undergoing important changes in terms of localisation and consumption. The overall global trend in potato consumption is characterised by increasing demand mainly driven by demand in the most dynamic markets of Asia and South America (EU Commission, 2010).

However, against the overall global increase in demand for potato products, the main consumption trends of interest to the Irish market is related to the overall decreasing trend for potatoes in more affluent societies. In the more developed economies of the world the demand for table potatoes is falling as consumers have become better off financially and eating way form home becomes more prevalent. In addition, the global demand for frozen and other processed potato products has increased in recent years.This trend is particularly evident in North America and Europe but is also becoming apparent in emerging global economies.

In Ireland, the trend for decreasing consumption levels and the parallel shift away from table potatoes and towards processed and frozen potatoes is evident. Figure 2 below shows the shift in consumption levels in potatoes in Ireland over the past two decades.

Figure 2:Total and Per capita human consumption: Ireland 1990 2010
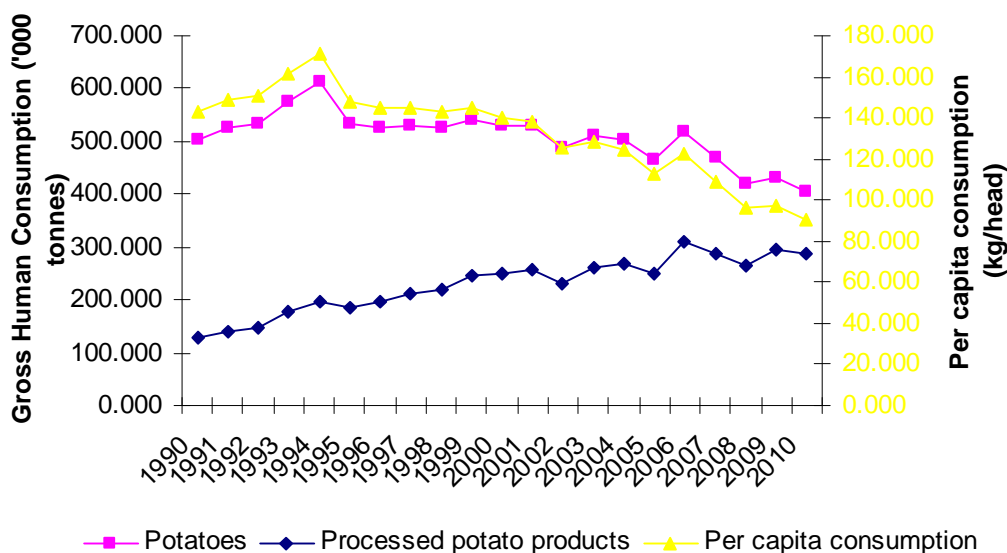
Source: Eurostat, various years

Figure 2 shows the decreasing trend in per capita consumption of potatoes over the past two decades. The main factors in the literature (EU Commisson, 2007), which have been cited as contributory factors impacting on the decline in human consumption of potatoes are:

- Demand for convenience products. Convenience is especially related to saving time due to busy lifestyles and more women in the workforce;
- An increase in competition of substitute products, such as pasta or rice;
- A strengthened attention on health aspects of food (such as slow calories and low fat).

In terms of the effect of recent consumption patterns on Irish production of potatoes there are two effects which could be considered as negative influencing factors on the outlook for the sector: (i) the decreasing overall demand for potatoes from the home market and (ii) the increase in demand for processed products which has not traditionally been serviced by domestic producers, rather it is serviced by imports from other EU countries.

2.3. Supply Chain Management

The majority of Irish potato growers grow for the fresh ware market and a grower may grow any combination of seed, early or main crop potatoes. The number of growers has continuously declined over the past two decades. Figure 3 below shows the number of holdings producing potatoes from 1990 to 2007 has declined by greater than 80 percent.

Figure 3: Number of holdings in Ireland producing potatoes (1990 2007)
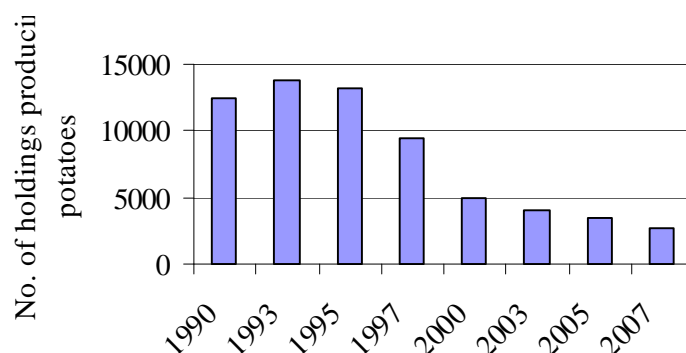
Source: Farm Structures Survey various years, [no newer data (>2007) available]

However further evidence from the Farm Structures Survey (FSS) shows that the reduction in potato growers has primarily come from growers with smaller holdings. As smaller growers leave the sector, production is becoming increasingly concentrated among a small number of larger growers. Table 2 below shows that the largest group of growers (> = 80 ESU's) account of just 11 percent of total grower numbers but account for nearly 80 percent of total area devoted to potatoes in Ireland. The average size of holding is jusy6 3.8 hectares but this varies

significantly from 0.1 hectares to 28.3 hectares in the smallest size grouping to the largest size grouping.

Table 2: Farmers growing potatoes classified by ESU and area under potatoes (2007)

Area under potatoes (hectares)	Economic size (ESU)							
	<2	2 - < 4	4 - < 8	8 - < 16	16 - < 40	40 - < 80	> = 80	Total
	000							
0 - < 1	0.2	0.2	0.4	0.5	0.5	0.2	0.0	2.0
1 - < 2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
2- < 5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.3
5 - < 10	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
10 - < 20	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
20 - < 50	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
> = 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.2	0.4	0.5	0.7	0.4	0.3	2.7
Area under potatoes (ha's)	0.0	0.0	0.1	0.2	0.7	1.2	8.0	10.3
Average area (ha's)	0.1	0.2	0.2	0.4	1.1	3.1	28.4	3.8

Source: Farm Structures Survey 2007

In terms of the structure of the sector post farm gate, historically the sector has been highly fragmented with the majority of production taking place on mixed family enterprise units serving local markets. However the structure of the sector has changed radically within the past two decades with the introduction of centralised distribution by retail multiples (Bord Glas, 2001). The vast majority of potato producers now sell their produce either directly to retailers or through pre-packers, merchants or wholesalers. Local market opportunities have diminished, particularly for those supplying retail multiples.

3. METHODOLOGY

3.1. Objectives and Hypothesis

The objectives of the paper are to evaluate (i) the factors influencing potato price formation at farm level in Ireland over the period 1992 to 2011 and (ii) whether or not potato price at farm level has become more or less volatile over time. To achieve these objectives an analysis of potato price at farm level was conducted during two time periods: 1992 to 2001 and 2002 to 2011. The effects of acreage reduction, concentration of production at farm level and also at market level , reduction in domestic consumption, and an increase in processed potato imports are assumed to be reflected in the price level and volatility.

The reduction in potato production is expected to have a positive effect on potato price level (similar to Loy *et al.,* 2011 and Pavlista and Feuz, 2005). The reduction in consumption is expected to have a negative effect on potato price level (similar to Loy *et al.,* 2011 and Pavlista and Feuz, 2005). The increase in demand for processed potato products is expected to have a positive effect on price (similar to Loy *et al.,* 2011 and Pavlista and Feuz, 2005).

The effect of production and market structure changes on potato price is difficult to ex ante suggest given that concentration at wholesale and retail market level has been increasing in addition to concentration levels at production level. The Irish Farmers Association (2011) estimated that the concentration of the buying power of the top three multiples, at nearly 80%2 of the retail market, '*…effectively weakens the bargaining power of the growers'. ….The actions of the retail multiples in aggressively competing for market share are constantly …. weakening the bargaining power of the grower in the potato supply chain.* The power of the retail; and intermediate sections of the supply chain in price formation has been the subject of international research in the potato supply chain previously (Richards *et al.,* 2001). The afore mentioned paper examined the processing potato sector in the USA and found that processors are able to exert oligopsony power to gain a market advantage over producers.

While concentration of market power in the intermediate and end stage of the supply chain in the Irish potato sector has been characteristic over the past decade, so too has the concentration of production within a smaller, more intensive group of farmers. Hence, structural change within the marketing and production frameworks of the Irish potato sector could be considered to be simultaneously counter balancing the effect on price formation.

In terms of the factors hypothesised to affect price volatility over the period 1992 to 2011, the shift in demand from table top potatoes to processed potato products is assumed to have a dampening effect on voalittility as observed in the US and German markets in the recent past (Loy *et al.,* 2011 and Pavlista and Feuz, 2005). Given that processed potatoes are less perishable than table stock potatoes, the demand for processed potatoes could be considered more price elastic. Hence if the market share of processed potato products increases, total demand becomes more price elastic.

The structural changes observed at market and production level over the past decade could also be proposed as having a dampening effect on price volatility. The larger, more intensive producers of potatoes (which are now producing a larger proportion of national potato production) could be assumed to have better management practises in place and as such have less volatile yields per hectare than smaller more extensive producers of potatoes. In addition, the presence of increased concentration of buying power in the Irish market could be considered to exert oligopsony power, hence dampening the effects of volatility.

3.2. Data

In this paper Central Statistics Office (CSO) data on potato prices at farm level are used for the period 1992 to 2011. This data is based on an index of potato prices comprising early and ate season potatoes. This data is available on a monthly and yearly basis. Potato and consumption production data is sourced from Eurostat Potato Supply and Use Balance Sheet data and is only available on a yearly basis. The Supply and Use data from Eurostat segregates consumption data based on whether or not the produce is processed or non processed stock.

Given that not all data is available on a monthly basis a more advanced econometric time series approach (such as the ARCH or GARCH methodology detailed in section 3.3 below) is not available for all independent variables that one would like to include in the model. Hence, due to data constraints in terms of frequency of observations a particular approach to precise measurement of price formation and volatility which involves presentation in both non technical and technical forms are used in this paper.

3.3. Methods to quantify the factors affecting price formation and volatility

Due to data constraints in terms of frequency of observations a particular approach to precise measurement of price formation and volatility which involves presentation in both non technical and technical forms are used in this paper.

3.3.1. Non technical analysis (Descriptive Analysis)

In this analysis a number of different analyses (less advanced econometrically than the time series ARCH modelling approach outlined in section 3.3.2) of the data were conducted to describe the (i) the factors influencing potato price formation at farm level in Ireland over the period 1992 to 2011 and (ii) whether or not potato price at farm level has become more or less volatile over time. This approach consisted of:

(i)   describing the yearly potato price variable in log terms over the period 1990 to 2010;

(ii)   calculation of a number of standard statistical measures of price volatility based on yearly and monthly potato price data: standard deviation, co-efficient of variation, annualised standard deviation (historic volatility);

(iii)   examination of the yearly price, production and consumption data from 1992 to 2010 to determine if certain factors were significant in the formation of potato price over time. The following relationship was estimated using OLS regression:

(1) $Price = b_O + b_1 Production + b_2 Consumption$

Where price is defined as the price of potatoes (in index form), production in tonnes (in thousands) of potatoes produced nationally and consumption in tonnes (in thousands) of potatoes produced nationally.

3.3.2. *Time Series Econometric Modelling of Price Formation and Volatility*

A number of approaches have been utilized in the economics literature to model time varying patterns of commodity prices. Of these the moving average (MA) model, autoregressive (AR) model, or the more general, autoregressive integrated moving average (ARIMA) model, were traditionally used to identify the structure of time series. In more recent times more complex models have become more popular in the literature such as autoregressive conditional heteroskedasticity models (ARCH) (Engle, 1982) and generalised ARCH models. (GARCH) (Bollerslev, 1986)**.** ARCH models allow the shocks in more recent periods to affect the current volatility positively while GARCH models suggest that previous shocks and previous volatilise affect current volatility.

In studies of price volatility it is common practise to consider the log return of the time series rather than the price series in levels. Hence, the log return (growth rate) for each series (variable) in this paper was calculated as *Ln [Pt / Pt-1].*

4. RESULT

4.1. *Descriptive Statistical Analysis*

An examination of Appendix 1 shows the log yearly potato price (1992 to 2010) and the log of monthly potato prices (1995 to 2010). An examination of the graph indicates that potato price has been extremely volatile within and between years over the time period examined. A second point to be noted in this graph is that decreased volatility appears to be displayed by both time series in the most recent years.

While the decreased volatility of the price series is evident in Figure 4, the extent of this decreased volatility is better captured by the lower co-efficient of variation[1] reported in Table 3 for the second half of the time series.

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1. [1] Co-efficient of Variation: A common statistic for measuring the variability of a data series , which expresses the dispersion of observed data values as a percent of the mean

Table 3: Summary Statistics 1995 – 2010 (Monthly data)

	Entire time series (1995 – 2010 monthly)	First time series (1995 – 2003 monthly)	Second Time Series (2004 – 2010 monthly)
Mean	1.000813	1.000659	1.000713
St. Dev.	0.047473	0.055661	0.035541
COV	4.74	5.56239	3.551535
Skewness	0.456825	0.497533	0.176197
Kurtosis	3.31784	2.243413	4.770652

In addition to determining the presence of volatility in the dataset, and that volatility appears to be decreasing over time, it is important to gain a better understanding of the factors affecting price formation within the dataset (second objective of the paper). It is important to note that while the overall price formation equation specified in section 3.3.1 above (and results outlined in Table 4) was significant, the relationship between price and production and consumption were not significant.

Table 4: Results of estimation equation 1, the influence of production and consumption on price

Parameter	1992 – 2010
Intercept	195.14**(64.5)
Production	-.434 (.337)
Consumption	.219 (.371)
R^2	.51
F Statistic	8.63**

Source: own calculations
Note: Standard errors in parentheses and * and ** denotes significance at the 0.05 and 0.01 level, respectively

While the relationships with the independent variables were not significant, the directions of the relationships were as one would expect. The regression shows that generally as potato production increased (decreased) each year, potato price decreased (increased). In addition, the results also show that generally as potato consumption increased (decreased) each year, potato price increased (decreased). Data constraints limit the addition of more years to the yearly dataset in order to determine if additional observations would alter the significance of the independent variables production and consumption in the price formation equation.

4.2. ARCH Estimation Results

Due to data restrictions in terms of frequency of availability, monthly data is only available for the potato price series, and only annual data for production and consumption data. Hence, to begin with, an ARCH model (MODEL I) is specified with only lags of the price variable included as explanatory variables. The dynamics of the time series are first examined using this model.

In accordance with guidelines provided by O'Connor *et al.,* (2009), as a starting point in the modelling of volatility in a time series it is important to determine whether or not the series behaves in a stationary or non-stationary manner. Hence, using the Augmented Dickey Fuller (ADF) test on the monthly time series price data, expressed in log terms, there is evidence to reject the null hypothesis of a unit root for the monthly time series (Table 5).

Table 5: Summary Statistics of Series

| Series	ADF Statistic	Critical Value 5%
Irish Potato price (monthly)	-19.192	-2.884

Following the methodology outlined by Moledina *et al.,* (2003) to compute conditional volatility a Lagrange Multipler (LM) test is required to test for the presence of ARCH effects. An ARCH(1) model is proposed and the ARCH(1) model is tested against the null hypothesis of no ARCH using the LM test. The results of this test revealed that no ARCH effects hypothesis was rejected at the 5% level, which suggests that the modelling process can proceed to the estimation of the ARCH model.

The ARCH (MODEL 1) estimated using the log of monthly potato prices from 1995 to 2010 was estimated with only one lag of price included (estimated as efficient by the BIC criterion). The parameter estimates of this model are shown in Table 6. The estimates confirm that the ARCH term's t-ratio is statistically significant' hence it can be concluded that the varience is autoregressive conditionally heteroskedastic. The estimated conditional volatility estimated based on this model is presented in Figure 4 below, which clearly shows that there is a lot more volatility earlier in the sample.

Table 6: Parameter estimates of ARCH MODEL 1 (One lag present)

logprice	Coef.	OPG Std. Err.	z	P>z	[95% Conf.	Interval]
logprice						
_cons	0.998845	0.002719	367.36	0	0.993516	1.004174
ARCH						
arch						
L1.	0.382629	0.1179282	3.24	0.001	0.151494	0.613764
_cons	0.001438	0.0000983	14.62	0	0.001245	0.00163

Figure 4: Conditional volatility for potato price, 1995 – 2010, monthly
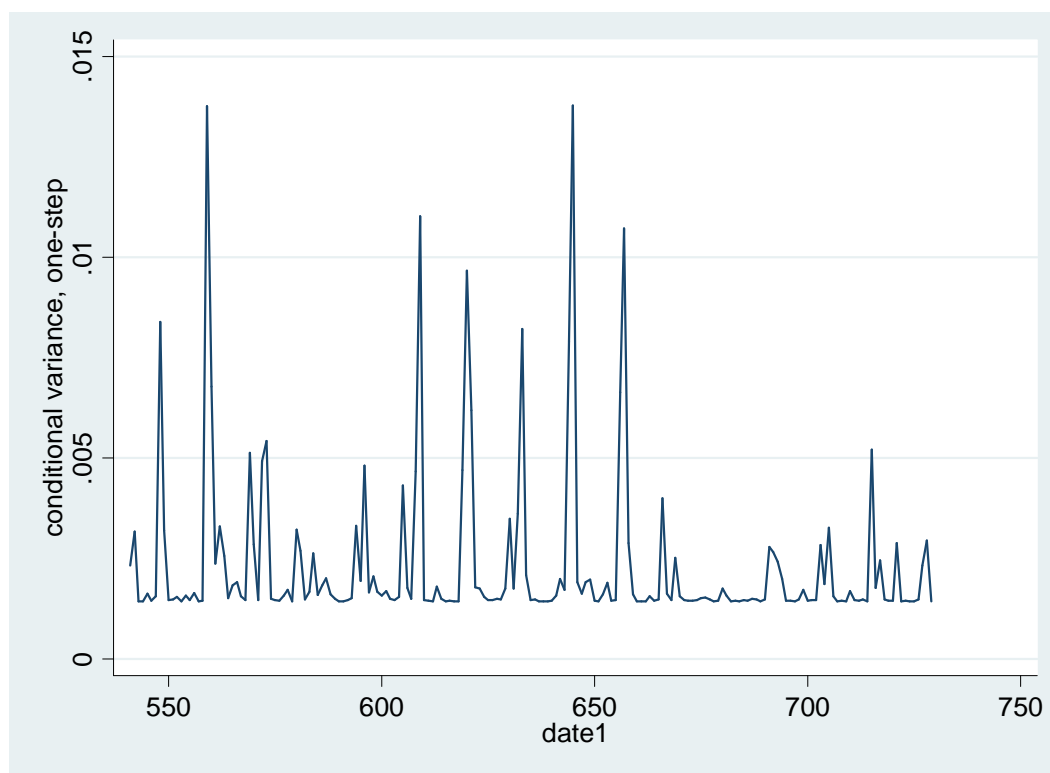
5. CONCLUDING REMARKS

The demand for Irish potatoes on the home market has undergone significant change in the last two decades. Eurostat report annual data on human consumption of potatoes on a kg per capita

basis; in 1990 this figure for Ireland was 144kg per capita , while most recent data for 2010 reports domestic consumption at 80kg per capita. In addition, during this time, the use of potatoes has shifted from consumption of table stock potatoes towards greater levels of processed potato products.

The supply of potatoes to the home market from domestic producers has also undergone significant change, with domestic production levels of potatoes reduced by just under 200,000 tonnes between 1990 and 2010.

Against this background of significant changes in domestic consumption levels and patterns and domestic production of potatoes this paper examined the effect of these factors on potato price levels and variability. Fresh potatoes are perishable products with virtually no carryover stocks between seasons. Thus, potato prices are expected apriori to adjust to short term changes in supply and demand.

In terms of the factors affecting potato price, the estimation resulted indicated that potato prices decrease with increasing volumes and increase with increasing consumption levels. .The estimated demand function for potatoes in Ireland has shown a structural break during the last two decades. While the demand for potatoes decreased, the price adjustments to changes in demand decreased significantly. Hence, it can be concluded that the demand for potatoes has become notably more price elastic.

Previous research by (Pavlista and Feuz (2005) and Loy, Riekert and Steinhagen, (2011) concluded that increases in the own price elasticity of demand for potatoes could be attributed to the increase in processed potato products on the market. Given that processed potato products can be stored over longer periods compared to table stock potatoes, the total demand for potatoes can become more flexible.

Preliminary research results for Ireland indicate that the direction and magnitude of the change in demand elasticity for potatoes are the same as for the US and German market. While this result could be indicative of the shift in the structure of demand (processed versus table stock), other factors such as supply chain organisational changes and production concentration levels could also be potential causes for the observed developments. Further investigation of the underlying factors contributing to the price responses need to be considered.

In terms of the implications of the observed findings at farm level, it is clear that if this trend continues to be observed in the future, Irish potato farmers can expect potato prices to become more stable and predictable. However, the corollary to this implication is that, stabilization of prices will lead to increased revenue volatility as yield fluctuations from year to year are not

counter balanced by responding prices. This will lead to higher aggregate financial risks of potato production in Ireland n the future.

6. ACKNOWLEDGEMENTS

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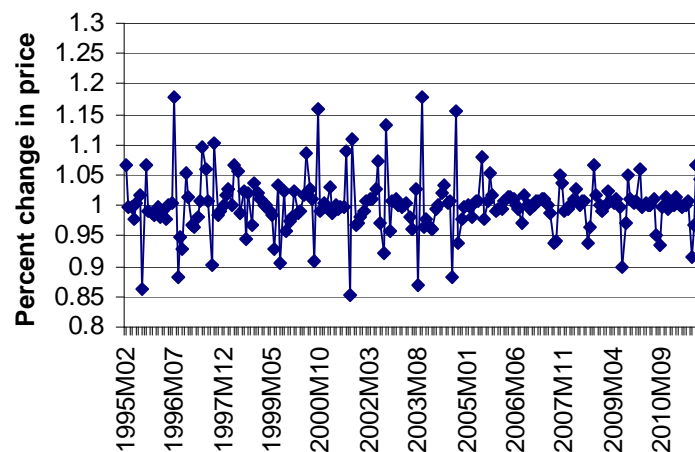
APPENDIX 1 – PRICE SERIES GROWTH RATES

(A) Potato Price Growth Rate 1990 – 2010 (Yearly)
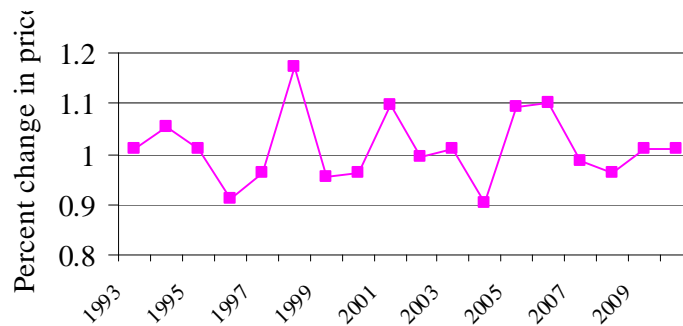
Source: CSO data and authors own re-basing and chain linking

(B) Potato Price Growth Rate 1995 – 2010 (Monthly)

Source: CSO data and authors own re-basing and chain linking