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An Econometric Model of Irish Beef Exports

Kevin F. Hanrahan

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Summary

This report summarizes research that the author undertook as part of his doctoral studies in the Department of Agricultural Economics at the University of Missouri-Columbia.[†]

The policy environment within which the Irish beef sector operates is changing such that the demand for Irish beef will increasingly be of a market rather than a policy determined nature. This changing environment makes knowledge concerning the demand for Irish beef important to understanding the economic prospects of the sector.

The objectives of this research were thus two fold. The first objective was to investigate the demand for Irish beef in the UK. The second objective relates to how such consumer demand models are econometrically estimated.

The empirical results show that the demand for beef in general in the UK is not price elastic and that the demand for Irish beef in the UK is price inelastic. The expenditure elasticity of demand for beef in the UK is also inelastic. The implications of this result for the Irish beef industry are as follows

- Decreases in the price of beef in the UK will not lead to large increases in British demand for beef.

- Increases in expenditure on meats will see expenditure on beef increase but to a lesser extent than other meats.

- Increases in the price of Irish beef relative to the prices of other beef products on the UK market will not lead to a large decrease in the market share of Irish beef.

- The relative insensitivity of demand for Irish beef in the UK to changes in its relative price also implies that attempts to increase the Irish share of the UK beef market will require very large reductions in the price of Irish beef.

Given the current dependence of the Irish beef industry on subsidized exports to non-EU markets, the results of this research imply that attempts to re-orientate the Irish industry more towards servicing EU beef markets will require either large price decreases, with the consequent impacts on the market based revenue of the Irish beef industry and farmers, or alternatively, a movement towards the production of beef products that appeal to the non-price concerns of EU consumers and away from the production of a commodity product.

Introduction

This research had two objectives. The first objective was to investigate the demand for Irish beef in the UK (Ireland's most important beef export market) using economic models based on the microeconomic theory of consumer utility maximization. The second objective of the dissertation relates to how such consumer demand models are econometrically estimated. Rather than use standard classical econometric procedures, a Bayesian methodology, based on recent developments in Markov chain Monte Carlo (MCMC) posterior density simulators, is developed and applied to the estimation of a set of meat demand models.

The demand for Irish beef in the UK was examined as part of a multi-stage demand system. If we examine this system from the "bottom up", Irish beef competes with beef products from other countries for its share of UK consumers' beef expenditure, in turn beef competes with other meats (such as pig meat, poultry meat and sheep meat) for a share of UK consumers' total meat expenditure, while the meat group competes with other foods for a share of overall consumer food expenditures.

Conceptually we can think of UK consumers' expenditure decisions as they relate to Irish beef in terms of what Deaton and Muellbauer call an "expenditure tree." Figure 1 starts with a predetermined level of expenditure on meat, thus this is strictly a "branch" of a larger tree. Given a defined level of expenditure on meat the consumer allocates expenditure across the four meats: pig meat goods, beef, poultry meat and sheep meat. This allocation decision determines the share of total meat expenditure spent on the four meats. Given prices (which the consumer cannot affect) this determines the quantity of beef consumed. This expenditure on beef is further allocated across the different beef products that "compete" for consumers' beef expenditure. In this research four beef products are modelled: UK produced beef, beef from Ireland, beef from other EU countries (i.e. from EU origins other than Ireland and the UK), and beef from non-EU origins.

What determines the demand for Irish beef in the UK? Neo-classical economic models of demand are based on the theory of a utility maximizing consumer. Given the satisfaction of certain conditions, a utility maximizing consumer's demand for a certain good x_i can be expressed as a function of the price of the good p_i, the price of other goods p_j, and consumer expenditure Y.

$$x_i = f\left(p_i, p_j, Y\right)$$

Figure 1. Meat Expenditure Tree
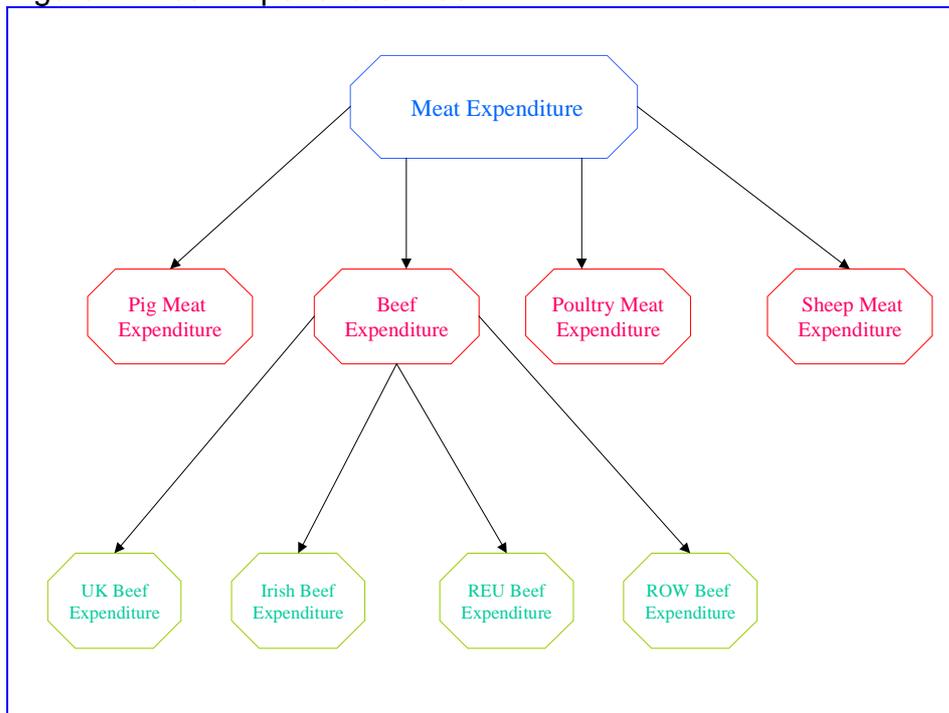
From theory, demand functions should possess a number of properties. These are known as regularity properties. Briefly they are that

1) The sum of expenditure on all quantities demand should equal total expenditure (the so-called adding up property),

2) if all price and incomes are increased by the same proportion that demand for all goods stays the same,

3) demand should not decrease with increased expenditure or increase with increases in price,

4) demands should be symmetric, i.e. the effect of a change in the price of beef on the demand for chicken should be the same as the effect of a change in the price of chicken on demand for beef,

5) Elasticity of substitution matrix should be negative semi-definite.

In this research our concern is with the demand for Irish beef in the UK. In investigating the demand for Irish beef in the UK we have to investigate the British demand for beef, as an aggregate good, since the demand for Irish beef in the UK is, on a priori grounds, a function of the demand in the UK for beef in general. The demand for Irish beef is thus also indirectly a function of the demand for other non-beef meat products and of the demand for meat in general.

Rather than use quantities as the dependent variable, expenditure shares are used as the dependent variable. UK expenditure on meat is allocated across four meat goods (beef, pig meat, poultry meat, and sheep meat) using a system of share equations that are functions of relative prices and the level of meat expenditure. UK beef expenditure is in turn allocated across 4 different

geographic sources (the UK, Ireland, other EU, and rest of the world) using a set of share equations that are strictly analogous to the expenditure share equation used to allocate UK meat expenditure.

The promise of flexible functional form based systems approaches to modeling consumer preferences, has, more often than not, failed to materialize in applied work. Estimated demand systems frequently fail to satisfy the regularity conditions of microeconomic theory at their point of approximation and for the sample space over which they are estimated. Also, estimated demand systems frequently indicate relationships between goods that are at odds with strongly held beliefs concerning the substitution and complementarity relationships between goods (Chalfant, Gray, and White,1991).

In this research a set of locally flexible functional form consumer demand system models was estimated using a Bayesian methodology known as Markov chain Monte Carlo posterior density simulation. This Bayesian approach allowed for the imposition of all the regularity conditions of microeconomic theory (see Hanrahan, 2000, and Hanrahan, Westhoff, and Young, 2001).

The choice of data sets and economic relationships examined was motivated by a desire to investigate the demand relationships for Irish beef in the UK. Because of European Union (EU) policy changes, the Irish beef industry's future economic prospects are likely to become increasingly dependent on market based demand rather than policy driven storage and subsidized export demand. The ultimate "applied economics" objective of this work was to obtain estimates of the effect on the demand for Irish beef of changes in meat prices and meat expenditures in the UK. Improved understanding of the demand relationships involving Irish beef will become increasingly important both to producers and processors of Irish beef as well as Irish agricultural policy makers as the policy reform process that began with the 1992 reforms of the CAP and which has continued with the recent Berlin Accord agreement continues to unfold.

In the remainder of this report the primary emphasis is placed on the results of the research in terms of price and expenditure elasticities of demand.

Motivation

Over the period 1973-1999, Irish beef consumption amounted to, on average, 17% of Irish beef production. Given the very small volume of beef imports into Ireland, this implies that over 80% of Irish beef production is exported. This extreme export dependence differentiates the Irish beef sector from other European beef industries, and has implications for how EU policy measures affect the Irish beef sector and for how the sector will develop in a policy environment in which government support of prices as a means of supporting farm incomes diminishes in favour of direct payments and other non-distorting policy instruments.

Figure 2: Irish beef exports: Total exports and Intra-EU exports
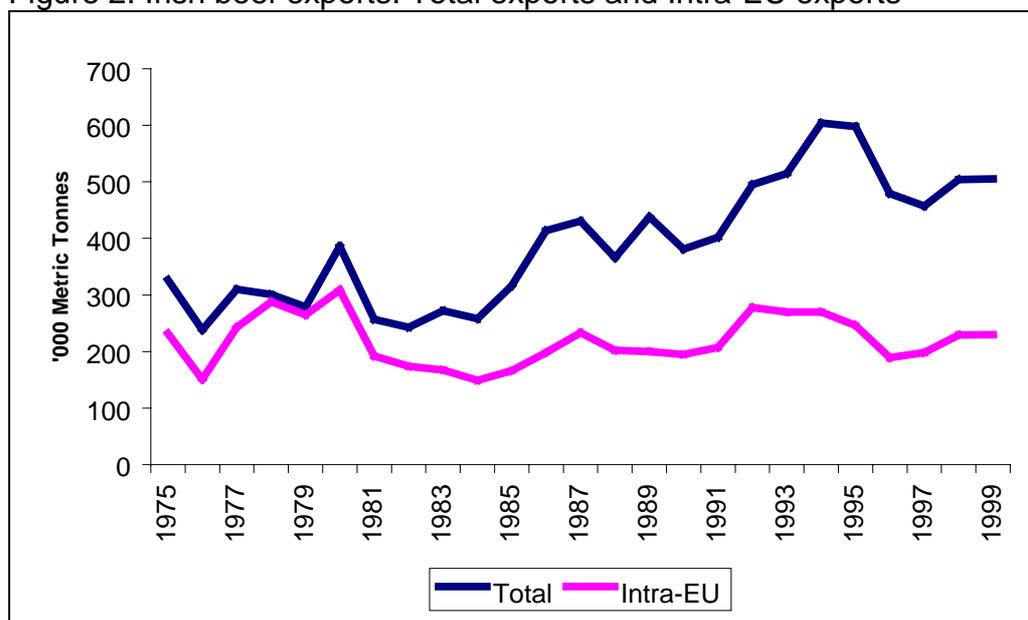
Source: USDA PS&D

Ireland's exports in tonnage terms to the EU market, which have not grown appreciably since the early 1980s, have changed somewhat in their composition. The United Kingdom, though it remains by far the largest importer of Irish beef, has declined somewhat in importance as import demand for Irish beef in other EU markets has grown. The decline in Irish exports to the United Kingdom mirrors the general decline in the total volume of beef imported into the United Kingdom.

Many EU commentators (Ockenden and Franklin, and Swinbank), as well as the European Commission itself, view the current and ongoing reform of the CAP as one in which support, which has heretofore been provided to farmers via price supports (and the associated protective tariffs, subsidized exports and intervention purchases), will increasingly be provided via direct payments. Demand for Irish beef will increasingly be commercially rather than policy determined. A lower beef price environment within the European Union can be expected to have both supply and demand effects, with lower prices leading to some contraction in supplies over time and expansion in demand.

For Ireland and the Irish beef industry, the important demand side questions are how will a lower price environment stimulate increased beef consumption within the European Union and to what extent will an increase in EU beef demand be reflected in increased demand for Irish beef. The extent to which lower beef prices lead to increased demand for beef in EU markets depends on developments in the prices of other meats and on the degree to which increased income or expenditure on meats translates into increased expenditure on beef. Ireland's share of the demand for beef in other EU markets depends on the price of Irish beef relative to that of the domestically produced beef and the price of

Figure 3: UK Per capita Meat consumption
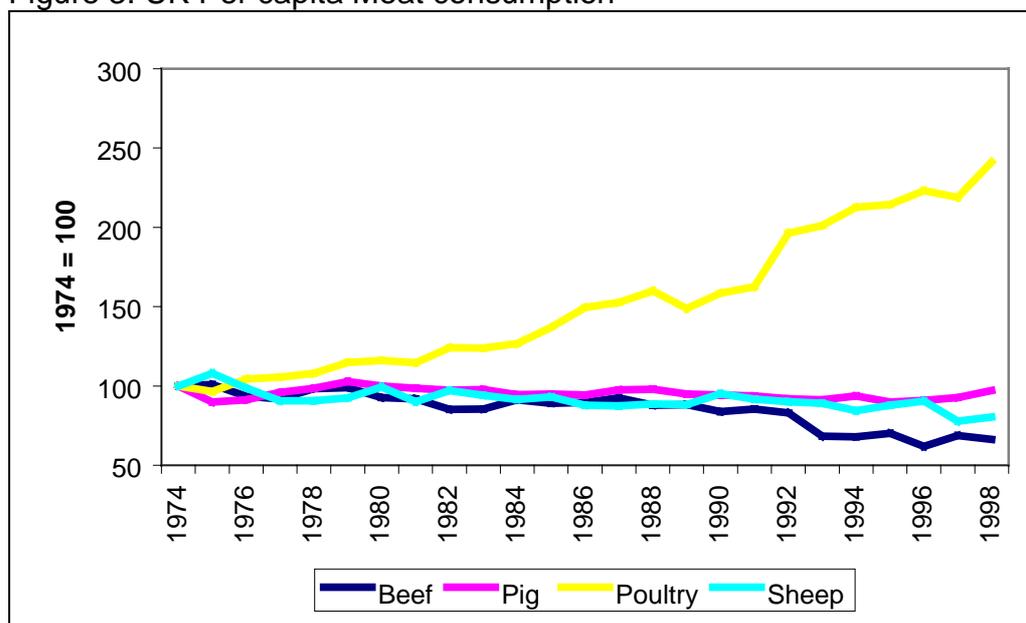
Source: FAO-Stat

beef imports from other EU members and non-EU countries and on the consumer preferences in these markets for beef from different origins.

Data Used

The models of consumer demand that were estimated are all interpreted in the context of a "representative" consumer's utility function. All retail prices are based on aggregate market data, while all of the quantity demanded data are per capita consumption (Kg/per capita) derived by dividing aggregate consumption (or imports) by total population. Data on population were obtained from the FAO-Stat database and are mid-year measures of population.

The data on UK consumption of beef, pig meat, and sheep meat are in carcass weight equivalents and each of these series were converted to retail weight equivalents using the following coefficients: 0.7 for beef, 0.7 for pig meat (from Thompson) and 0.59 for sheep meat (from the UK Meat and Livestock Commission (MLC) European Handbook). The data on the consumption of poultry meat is in ready to cook weight equivalent.[1] The conversion coefficients used to translate carcass weight to retail weight were applied over the entire sample period. This implies an assumption that the cut-out weights between the wholesale and retail levels for beef, pig meat and sheep meat have been constant over the period 1974-1998. This assumption is most likely false; however, in the absence of other information these conversion factors are used. The aggregate consumption data, which are in metric tons, were then converted

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[1] See the discussion on the FAO-Stat web site, http://apps.fao.org/.

Figure 4: UK Retail prices meat
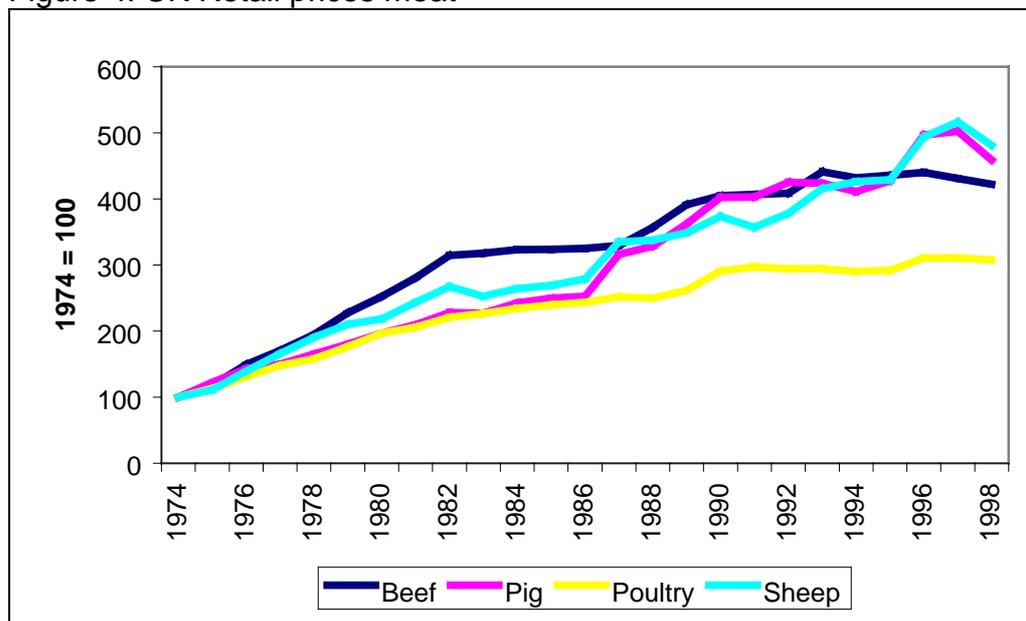
Source: ONS

to kilogram per capita consumption equivalents by dividing by total UK population.

Figure 3 graphs UK per capita meat consumption used, where the quantity of each of the meat goods consumed in each year is measured relative to the level of consumption of that good in 1974. The most striking pattern that emerges from these data is the rise in per capita consumption of poultry meat and the decline in the per capita consumption of beef over the sample period. UK consumption of beef and poultry meat in 1974 was 17.18 and 9.03 kilograms per capita, respectively; by 1998 the levels of consumption for these two meats were 11.39 and 21.78 kilograms per annum respectively, a fall of over 33% in per capita beef consumption and an increase of just over of 141% in poultry meat consumption.

These trends are similar to those seen over the same period in other countries' meat markets (Brown). These developments have led to arguments that there has been a shift in the preference structure of consumers away from beef and towards poultry (Chalfant and Alston, and Alston and Chalfant). The changing UK meat consumption basket has prompted research on whether preference shifts rather than price and income effects account for these dramatic changes (Burton and Young, 1991).

Figure 5: UK meat expenditure shares
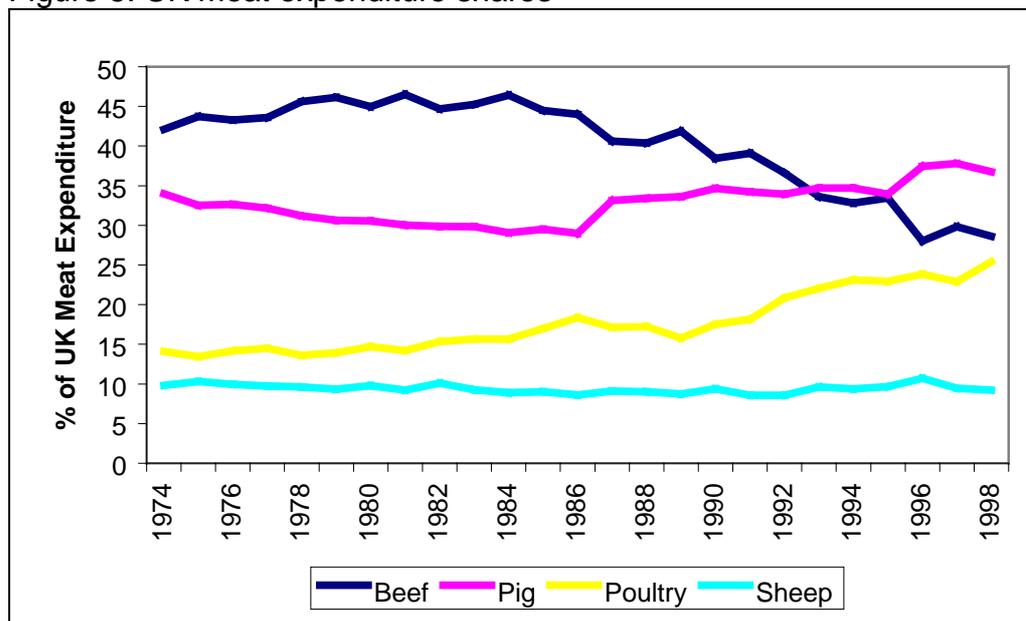
Source: ONS, FAO-Stat

The dramatic decline in the consumption of beef, especially since 1992, is at least in part due to the effects of the so-called ``BSE crisis''.[2] Recent research by Burton and Young has indicated that the BSE crisis may explain a large part of the decline in UK beef consumption during the early 1990s.
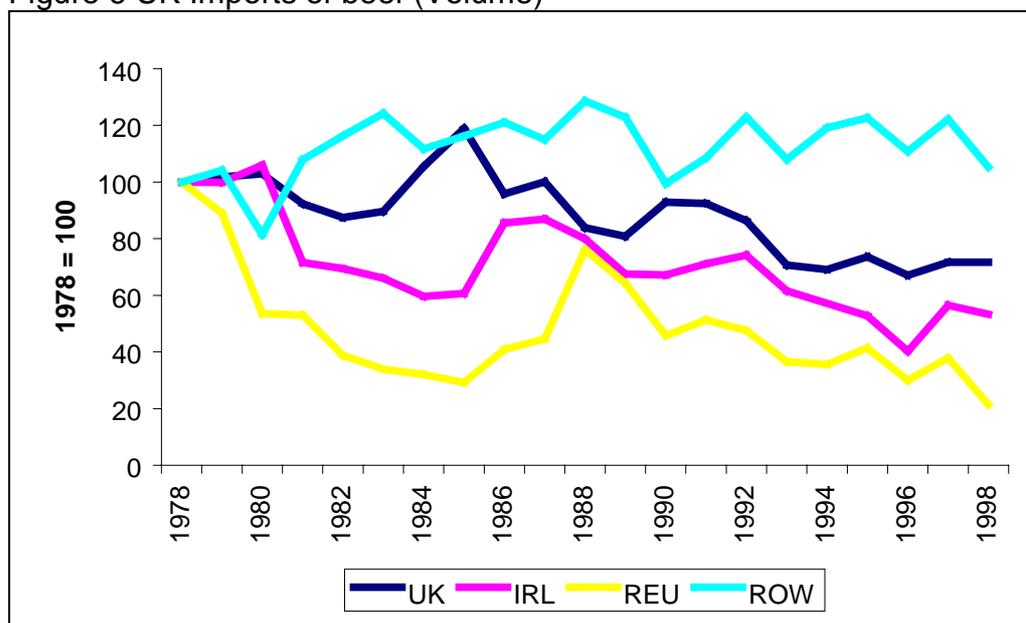
Retail meat prices in the UK over the sample period are graphed in Figure 4. Retail price index data at a slightly more disaggregated level were obtained from UK's Office for National Statistics (ONS).[3] These disaggregated price indices were aggregated into four retail price index series using the weights with which the different goods enter into the calculation of the UK's consumer price index. Using 1994 monthly retail price data in levels for the four meat goods, also obtained from the ONS, the retail price indices for the four meats were used to derive a set of price series for the period 1974-1998.

The movement in the relative prices of the four meat goods in the UK over the sample period is similar to that observed in other EU countries. The price of beef relative to that of poultry meat has risen dramatically. In 1974 the percentage

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[2] The discovery of a possible link between bovine spongiform encephalopathy (BSE) and the human neurological disease Creutzfeld-Jacobs disease and the announcement of this possible link in the British Parliament led to a large fall in beef consumption in the UK and across the EU. British beef exports were banned and other measures involving the culling of all bovines over a certain age were introduced in attempts both to restore consumer confidence and limit the affect of the disease on the British beef sector. BSE infected animals have been identified in other EU member states.
[3] The data acquired from the ONS consisted of retail price indices for both imported and domestically produced lamb, bacon and pork, as well as series for beef and poultry meat.

Figure 6 UK Imports of beef (Volume)
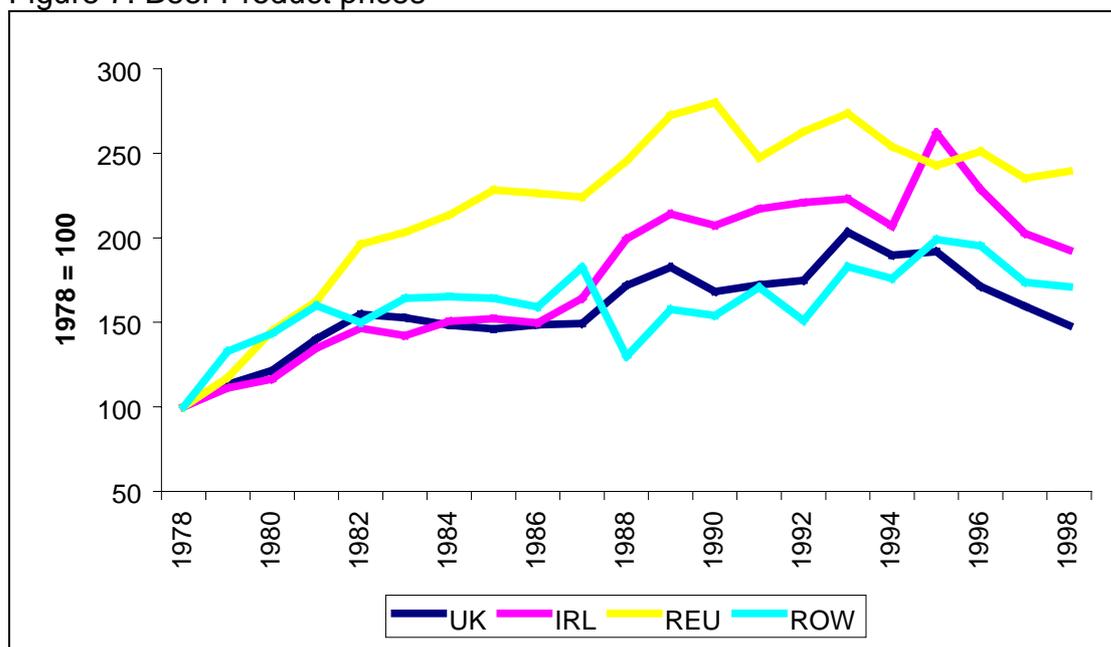

Source: Eurostat, FAO-Stat.

differential between UK beef and poultry prices per kilogram was 103%; by 1998 the differential had increased to 180%.

The evolution of the expenditure shares of the four meats in the UK over the sample period (Figure 5) reflects the developments in quantities consumed and the retail prices of the four meats. Despite the dramatic rise in the quantity of poultry meat consumed per capita, the low rate of increase in poultry prices, relative to the other meats, has meant that the increase in the expenditure share of poultry has been less dramatic. The expenditure shares of these two meat goods, which in 1974, were 42% for beef and 14% for poultry, had by 1998 changed dramatically, with beef down 29%, while the share of poultry meat in the UK consumers' meat basket had risen to 25%. The expenditure share of pig meat has by the end of the period overtaken that of beef, while expenditure on sheep meat (mutton and lamb) had fallen marginally.

In the UK beef import demand model the bundle of goods comprises of UK consumption of UK produced beef, UK consumption of beef imported from Ireland, UK beef consumption of beef imported from EU member states other than Ireland, and UK consumption of beef imported from non-EU countries.

SITC Revision 3 trade data (at the 5 digit level), on the volume and value of UK imports of beef for the period 1977 to 1998 were obtained from Eurostat. These data were aggregated, after converting bone-in volumes and values to boneless equivalents, to form a set of 3 UK beef import series (volume and value) series: UK imports of beef from Ireland (IRL), from other EU member states (REU), and

Figure 7: Beef Product prices

Source: Eurostat, FAO-Stat.

UK beef imports from non-EU member states (ROW).[4] The aggregated beef import value and volume data were used to construct implicit unit value price series. These unit values were used as the demand prices of the associated imports in the absence of other bilateral trade prices.
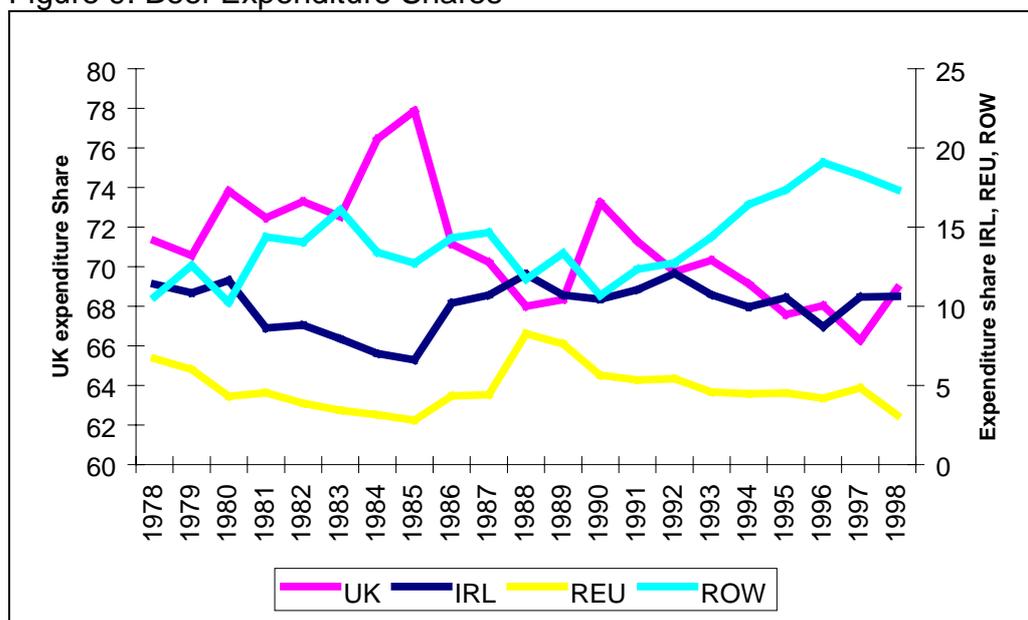
The quantity of UK produced beef consumed in the UK is derived from a supply and utilization identity (full details are available in Hanrahan). The data used are from the FAO-Stat database and are approximately consistent with the carcass weight equivalent SITC UK beef import data.[5]

The price associated with the demand for UK beef is a wholesale carcass price obtained from the UK Meat and Livestock Commission (MLC). The absence of origin specific retail price data precludes the use of retail data in the import demand model. The use of wholesale prices as a proxy for the retail price of the domestically produced product and of unit values as proxies for the demand prices of imported products is standard in the empirical trade literature, see Brenton, and Yang and Koo.

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[4] The coefficient used to convert bone-in beef volumes and values to boneless equivalent were taken from the UK Meat and Livestock Commission's European Handbook. The coefficient is constant over the time period examined. This implicitly assumes that the cut-out weight of meat from bone-in beef did not change over the period 1977 to 1998. This assumption is unlikely to be valid.

[5] Over the sample period (1977-1998) the average discrepancy between the supply and utilization data on aggregate imports of beef (carcass weight equivalent) and the aggregate level of beef imports from the SITC data set amounted to 2.5% of the total supply and utilization import total from FAO-Stat.

Figure 9: Beef Expenditure Shares

Source: Eurostat, FAO-Stat.

All of the quantity data (consumed and imported) were divided by a UK population series to give per capita demands for the different beef products. Indices of the per capita quantities of UK produced beef, and imported beef products consumed in the UK and of the prices of these different beef products are shown in Figures 6 and 7.

The data on the prices of and quantities of the four different beef products were used to derive expenditure shares. Unsurprisingly, UK produced beef has the largest market share in the UK. Ireland's share of the UK beef market declined following accession to the EU. During the latter half of the 1980s the expenditure share of Irish beef recovered somewhat so that by 1998 the expenditure share of Irish beef is roughly equal to that in 1978. The share of British produced beef and beef from other EU member states has declined over the period 1978-1998, while the share of beef from non-EU countries has grown.

Figure 8 graphs the expenditure share of the beef imports and that of UK produced beef in the UK beef consumers' basket. The left axis of the figure relates to the UK share while the right axis relates to the shares of the other three beef product demands that were modelled.

Empirical Results

The empirical results obtained are presented in the form of Hicksian price and expenditure elasticities of demand. Full details of the estimated model parameters (and other elasticity measures are available in Hanrahan). The results presented here are based on a log translog specification of the UK meat

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Table 1: Hicksian elasticities: Fully regular Log Translog demand system

	Beef	Pig Meat	Poultry	Sheep Meat	Expenditure
UK Meat Demand Model					
Beef	-0.918	0.095	0.776	0.047	3.300
Pig Meat	0.108	-0.441	0.107	0.227	0.949
Poultry	1.582	0.203	-2.427	0.643	-4.564
Sheep Meat	0.209	0.793	1.193	-2.195	2.443

demand model and an AI demand system specification of the UK beef import demand model.

An elasticity is a measure of the extent to which demand for a good responds to a given change in either price or expenditure when all other things are held constant. A price elasticity measures the responsiveness of demand to change in price and an expenditure elasticity measures the responsiveness of demand to a change in the level of consumer expenditure. A price elasticity of less than 1 implies that for a 1% change in the price the change in the quantity demanded will be less than 1%. Theory and common sense would lead one to expect that an increase in price, for example the price of beef, would lead to a decrease in the quantity of beef demanded and an increase in the quantity of alternative meat goods demanded. This prior belief would lead one to expect that the own price elasticities of demand, which are on the diagonal of the elasticity table should be negative, and that the off-diagonal elements, the cross-price elasticities, should be positive.

Theory does not suggest, a priori, what the sign of the expenditure elasticities should be. A positive expenditure elasticity of demand implies that as the level of expenditure increases the quantity of the good demanded also increases. When the expenditure elasticity is positive, but less than 1, then the increase in quantity demand in response to a 1% increase in expenditure will be less than 1%. A negative expenditure elasticity implies that as expenditure increases the quantity of the good demanded declines, all else held constant.

As is clear from Table 1 the elasticity results obtained with the log translog demand system specification fit with both theoretical and common sense beliefs, i.e. all are negative. The own price elasticity of demand for beef in the UK is almost unit price elastic, its value in absolute terms is a little in excess of 1. This means that if the price of beef fell, the quantity of beef demand by UK meat consumers would be expected to increase by slightly more than 1%. UK pig meat demand is the most price inelastic, while poultry meat demand is the most price

Table 2: Hicksian Elasticities: Fully regular AI Demand system

UK Beef Import Demand Model					
	UK Beef	Irish Beef	REU Beef	ROW Beef	Expenditure
UK Beef	-0.365	0.040	0.143	0.183	1.136
Irish Beef	0.265	-0.684	0.194	0.215	1.303
REU Beef	2.190	0.417	-1.707	-0.892	1.786
ROW Beef	0.920	0.150	-0.297	-0.773	-0.174

elastic. This finding fits with a prior belief that pig meat is a staple product in the British diet whereas poultry meat, as of yet, is not.

The own price elasticities of demand for beef of different country of origin,(see Table 2) also fit with prior beliefs concerning demand for home products versus imported substitutes, in that demand for UK produced beef in the UK is more price inelastic than demand for imports. Thus, for an equal increase in price the demand for UK beef would fall less than the demand for imported beef products. The demand for Irish beef is, nevertheless also price inelastic. When combined with the near unit elastic demand for beef in general, this finding has implications for the effectiveness of a strategy of pricing increased volumes of Irish beef onto the UK market.

The cross price elasticities of demand for meat and beef products that are reported in Tables 1 and 2 on the whole reflect prior beliefs that the four meat goods and four beef products modeled are substitutes. A substitute relationship in demand between two goods means that as the price of one increases, the demand for the other increases as consumers reduced the quantity consumed of the good that has increased in price and, to "compensate", increase their consumption of the substitute good. A complementary demand relationship, is the opposite of the substitute relationship, an increase in the price of one good leads to a decrease in the quantity demanded of the other good. These relationships are reflected in the off-diagonal elements of the elasticity matrices reported in Tables 1 and 2. Prior beliefs would lead one to expect that these cross price terms would be positive. Some cross price elasticity results that are counter-intuitive arise in both the beef import demand model's results.

Implications

Since Ireland's accession to the EU in 1973 the Irish beef industry, under the aegis of the EU's Common Agricultural Policy, has been very reliant on policy determined demand for its output. The changed and changing EU policy environment will mean that increasingly the demand for Irish beef will be of a commercial rather than of a noncommercial (i.e., policy determined) nature. At both the producer and processor levels, the market returns to beef production will

increasingly be a function of the price competitiveness of Irish beef products on other EU markets (and possibly on the wider world market) and on consumer's perceptions of Irish beef in terms of quality and safety concerns relative to beef produced in other countries.

The results of the UK meat demand model imply that the most elastic demand is for poultry while the most price inelastic demand is that for pig meat. The own price elasticity of demand for beef in the United Kingdom is unit elastic. This relative inelasticity of demand for beef has implications for how the demand for Irish beef in the United Kingdom changes in response to changes in price. In addition the UK the expenditure elasticity of demand for beef in the UK, while positive, is less than one. This implies that if UK consumer incomes rose by 1% that the demand for beef would rise but by less than 1%. Relative to the other meats the expenditure elasticity of demand for beef is the largest, implying that in the absence of changes in relative prices, increases in consumer incomes should lead to increases in the quantity of beef consumed relative to other meats.

The results from UK beef import demand model results indicate that the demand for UK produced beef is much more inelastic than the demands for non-British beef. The Marshallian own price elasticity of demand for Irish beef in the United Kingdom is less than -1.0, implying that the demand for Irish beef is also inelastic.

The price inelasticity of demand for Irish beef implies that lower Irish beef prices in the UK market would not greatly increase UK market share of Irish beef. The expenditure elasticity of demand for Irish beef of 1.303 implies that as expenditure on beef increases the Irish share of that expenditure increases. The converse of this is that when there are decreases in total beef expenditure the percentage decline in the quantity of Irish beef consumed is greater than the decline in consumption of UK produced beef.

The counterintuitive negative Marshallian cross price elasticities of demand between UK produced beef and Irish beef imply that the demand for Irish beef falls as the price of UK beef increases and similarly the demand for UK beef falls as the price of Irish beef rises. The relative magnitudes of the two Marshallian elasticities are such that the UK produced beef price has a greater effect on the demand for Irish beef than the price of Irish beef has on the demand for UK produced beef. The counter-intuitive gross complementary relationship between Irish beef and UK produced beef on the UK beef market may be caused by the absence, historically, of any attempt to distinguish these two products. Recent European legislation will require country of origin labels on all beef products so this practice will no longer be possible.

It might be expected that the greater geographic differentiation of beef products required by recent EU legislation may increase the effect of national preference in consumer beef purchases. Other things being equal, such a development

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would be expected to make the own price elasticity of demand for UK produced even more inelastic with respect to price and make the demands for imported beef product more inelastic in an own price sense. The increased importance of market outlets for beef produced in Ireland and the concomitant decline in importance of policy driven demand means that the Irish beef industry will have to price Irish beef onto other EU beef markets or market Irish beef in a way that responds to EU consumer's non-price concerns. The success of a strategy of pricing Irish beef onto other EU markets depends on a number of factors. Among others these include the following: the price sensitivity of EU consumers' demand for beef vis a vis other meats, the extent to which national preference factors emerge in EU beef markets that would be expected to reduce the own price elasticity of demand for domestically produced beef; and the price sensitivity of demand for Irish beef on these markets. For an industry that has been so reliant on non-market determined demand the latter strategy, while offering the potential for lucrative markets, is unlikely to provide outlets for the bulk of Irish beef production.

The results of this research indicate that the elasticity of demand for Irish beef in the United Kingdom is inelastic. If similar results were found in other EU beef markets any attempt to increase market share through lower prices would not dramatically increase the demand for Irish beef.

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