The demands they are a-changin’

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Abstract

Smooth operators such as time trends are often applied to deal with unidentified demand shifters. However, if unknown factors affect demand irregularly, a time trend fails to capture the variation. We present an index approach for estimating irregular demand shifts, decomposing total demand shifts into predicted and unexplained effects. This allows separating demand shifts caused by known factors like income and substitution effects from unknown impacts on demand. Our application on farmed salmon shows unknown factors impact demand irregularly both between regions and within regions over time. Unknowns contribute to more than half of global salmon demand growth in recent years.

Keywords: demand growth, farmed salmon, market analysis, aquaculture economics, seafood

JEL Classification: D12, Q22

1. Introduction

"As we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know."

(Rumsfeld, 2002)

How important is the unknown? Demand shifts for any good may be caused by well-known economic variables such as changes in income and substitute prices as well as consumer characteristics such as demographic variables, which an econometrician might be able to quantify (known knowns). Demand shifts may also be caused by factors that are known to the researcher, such as a proliferation of varieties of value-added product forms or a reduction in consumers' transportation costs, but where it is too difficult to quantify their effects (known unknowns). There may also be some variables affecting demand that are unknown to the researcher (unknown unknowns). As advocated by Mr. Rumsfeld, we argue that it is important to focus not only on what we know, neither in politics nor demand analysis. Unknowns may be equally, if not more important. In this article we present an approach for calculating irregular demand shifts caused by unknown factors (known and unknown unknowns), building on an index approach of Purcell (1998).

Demand shifts can cause volatile or high food prices, which are a challenge to impoverished and poor producers and consumers, food industries, and also a potential source of social unrest (Bellemare, 2015; Dawe & Peter Timmer, 2012; Ivanic & Martin, 2008). If causes of demand shifts are not well understood, it is near impossible to make reasonable expectations about, or prepare for, future shifts in demand and their potential impacts. An important step to better understand demand is to determine the relative importance of both its known and unknown impacts. Ignoring unknowns is only tolerable if they are not important.

Furthermore, when markets are integrated globally, demand shifts in one region impact prices and quantities in other regions. Thus, to better understand demand, price and quantity changes for a commodity when its markets are globally integrated, it is useful to analyze all regions where it is consumed. An almost ideal starting point for such an analysis is having access to panel data for all markets of substantial consumption. This would allow the researcher to account for irregular demand shocks by including interaction terms between the fixed effects and a time variable[1]. However, when analyzing demand for a global food commodity, access to data is often limited. Thus, in the absence of detailed panel data across multiple regions one needs to use alternative methods, of which this paper advocates an approach for calculating irregular demand shifts.

Analyses of demand and supply shifts have similarities and differences. The effect of exogenous shocks like weather changes and seasonality as well as group effects such as household or firm effects are handled in similar manners. This is also the case for smooth changes in preferences or technical change over time, which can be represented with a trend variable. However, if technical change or changes in preferences are not smooth, the approaches to measuring these effects are very different. A sophisticated tool kit has been developed to analyze the impact of technological change on the behavior of the firm using techniques such as stochastic frontiers and indices (e.g. Coelli, Rao, O'Donell, & Battese, 2005; Kumbhakar & Lovell, 2000). For the demand side, the literature on demand growth have mainly relied on using smooth operators such as a time trend (Stone, 1945; Deaton & Muellbauer, 1980), sometimes augmented by relatively smooth variables like advertising expenditures or media coverage (Kinnucan et al. 1997; Brown and Schrader 1990). Non-systematic demand shifts have received less attention, despite the large literature on the parallel feature on the production side in terms of technological change.

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[1] We wish to thank an anonymous reviewer for noting the possibility to account for irregular demand shocks when panel data are available.

Pollak (1970) provides a theoretical foundation for smooth consumption paths, arguing that consumption in previous periods influences current demand and preferences for a product. He refers to this as *habit formation*. Pollak and Wales (1995) show how exogenous factors like advertising can influence demand in a similar fashion to demographic variables via demographic scaling or translating. Stigler & Becker (1977) take the position that tastes and preferences do not change over time, but that the accumulation of *consumption capital* from consuming a product in previous periods influences current quantity demanded. Pollak (1978) later argues that the differences between these two perspectives are merely a matter of semantics, not substance. Stone (1945) suggests that time trends, either linear, quadratic or sigmoid, should be used to allow for systematic changes in demand. Barten (1967; 1969) follows this approach and introduces a constant term in the Rotterdam-system to allow for gradual changes in preferences. However, as suggested by the technical change literature, it is far from obvious that time trends are appropriate to account for changes in demand over time if they are not smooth.

Demand growth or contraction may occur for a number of reasons. Economic causes are changes in income and changes in the prices of substitute and complementary products, which are usually explicitly accounted for in demand analyses. Other sources of demand shifts are changes in demographics (Tomek, 1985); changes in socioeconomic factors (A. Brown & Deaton, 1972); the appearance of new information of a product or accumulation of consumption capital (Stigler & Becker, 1977; Tomek, 1985); changes in product attributes such as product forms and quality (Ladd & Suvannunt, 1976). Furthermore, Becker (1965) argues that consumers are also producers; by combining time and inputs (like food and cooking equipment) they produce commodities (meals, for instance) according to the cost-minimization rules of the traditional theory of the firm. Increasing incomes increase the opportunity cost of using time as an input, while growth in capital and technology increases the productivity of the consumer's time[2], thus reducing the amount of time needed to produce a commodity. Changes in the productivity or opportunity cost of the consumer's time will in turn affect the demand for food inputs. In addition, the rapid expansion of supermarkets in emerging markets can have a major impact on demand for a vast number of food commodities (Reardon, Timmer, & Berdegue, 2004). The "supermarket revolution" is likely to reduce consumers' transportation costs, modernize food procurement systems (Reardon, Timmer, & Minten, 2012), affect the quality requirements of the product (Dolan & Humphrey, 2000), increase the supply of convenience foods (Senauer, Asp, & Kinsey, 1991), all factors which will affect demand. Whether demand growth is analyzed at the retail or farm level (M. K. Wohlgenant, 1989), and how aggregated the product in question is (Eales & Unnevehr, 1988), will of course also affect the complexity of the analysis. Changes such as those mentioned above are likely to occur interdependently and simultaneously over time, and data availability often prevents most of these factors from being included in econometric demand models. Even if data on all potential demand shifters is available, the researcher will most likely run into issues of endogeneity and collinearity between variables, and thus might end up omitting some or most of the variables anyway (Tomek & Robinson, 2003). The researcher will then often rely on time trends to try and capture the effect of omitted variables, but as noted by Stone (1945), if any influence on demand has been irregular over time, omitting it from the analysis will impair the results.

The notion of non-systematic or irregular demand shifts is not new; a substantial number of studies have investigated whether changes in consumption patterns are caused by structural changes in demand (e.g. Chalfant & Alston, 1988; Eales & Unnevehr, 1988, 1993; Moschini & Meilke, 1989). Okrent & Alston (2011) discuss various methods for detecting structural change; Nonparametric methods can be used to test if data are consistent with

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[2] One example of technology improvement is the introduction of microwaves in households (Park & Capps, 1997).

axioms of revealed preferences. However, such nonparametric tests tend to have low power, and cause a tendency to under-reject the hypothesis of stable preferences (Alston & Chalfant, 1991a). For parametric approaches, Othani & Katayama (1986) include a gradual transition parameter to detect gradual changes in demand, which provides a more sophisticated alternative to using time trends or discrete intercept-shift dummy variables. This gradual transition approach has later been applied to several demand analyses (e.g. Asche & Zhang, 2013; Dong & Fuller, 2010; Moschini & Meilke, 1989). However, detecting demand shifts in parametric approaches is not unproblematic either; testing for structural change is difficult, especially when the same data are used both for estimating demand equations and for testing their stability (Chalfant & Alston, 1988). Findings of structural change in demand analysis can be due to changes such as those mentioned in the previous section, as well as due to methodological issues caused by model specification errors such as using the wrong functional form or neglecting important variables (Alston & Chalfant, 1991a, 1991b; Stigler, 1966). For instance, if demographic variables have an impact on expenditure and/or price elasticities, incorporating endogeneity in expenditure and/or price in demand systems is necessary to avoid biased and inconsistent parameter estimates (Hovhannisyan & Gould, 2011).

Specifically, vast efforts have been carried out to explain changes in U.S meat consumption patterns (see for instance Piggott & Marsh (2004) and references therein). This research has yielded mixed evidence, and there is no consensus whether changes in consumption patterns are caused by changes in relative prices and income alone, or whether other factors also impact demand.

Taylor & Taylor (1993) take a different approach, and split demand growth for interstate telephone calls into predicted and unexplained growth, or what Mr. Rumsfeld would describe as splitting demand growth between known knowns and the combined impacts of known unknowns and unknown unknowns. The predicted growth is due to changes in prices, income, and population growth, while the latter is a residually measured in part due to other factors not explained by their model. The total, or gross, shift in demand is the sum of predicted and unexplained demand shifts.

Karagiannis & Velentzas (2004) explain changes in consumption patterns by decomposing the expenditure shares/quantity demanded of different goods into a total substitution effect, an income effect, and a habit effect. First they estimate a QUAIDS (Quadratic Almost Ideal Demand System) model before using the unconditional elasticities from the model to calculate the aforementioned effects.

Marsh (2003) use a method for measuring total shifts in demand that vary independently between years in the form of an index approach, and apply the index to measure demand shifts in the US retail beef market. The approach was popularized by Purcell (1998), and has in recent years been applied to create demand indices for salmon and lamb (Asche, Dahl, Gordon, Trollvik, & Aandahl, 2011; Brækkan & Thyholdt, 2014; Shiflett, Purcell, & Marsh, 2007) as well as several product forms of beef and pork in the US (Tonsor & Schroeder, 2017). We extend the approach by decomposing the total demand shift into predicted and unexplained impacts on demand, in line with the distinction made by Taylor &Taylor (1993) and Karagiannis & Velentzas (2004). This allows determining the direction and the magnitude of shifts caused by both known and unknown demand shifters. In particular, it allows for the separation of shifts caused by economic factors such as income and changes in substitute prices, the effect of other known factors such as seasonality, and the combined impact of other factors (unknown unknowns and known unknowns) that can be interpreted as the effect of unidentified and omitted variables. To simplify articulation we henceforth refer to *known unknowns* and *unknown unknowns* as simply *unknowns*.

Our approach is illustrated with an application to the global demand for farmed salmon. Aquaculture has been the world’s fastest growing food production technology during the last decades (Food and Agriculture Organization of the United Nations Statistics Division, 2015; Smith, Roheim, & Crowder, 2010), and salmon production has been growing faster than aquaculture in aggregate. As production has increased, the market has expanded in geographical as well as product space (Asche and Bjørndal, 2011), which is perceived as demand growth from the producers´ perspective. During the last decade production growth has been on average 6 percent annually with a relatively stable price, indicating substantial demand growth. The salmon market thus provides an excellent example for computing demand shifts in different regions of the world, and assigning the shift to known and unknown factors.

2. **Deriving a shift in demand**

A demand shift is characterized by a movement of the demand schedule. This movement may be measured either horizontally or vertically (M. M. K. Wohlgenant & Lusk, 2011). A horizontal shift can be interpreted as the change in quantity demanded at a given price, while a vertical demand shift can be interpreted as the change in consumers’ willingness to pay for a given quantity. Following the Marsh (2003), we start by illustrating a shift in demand in the quantity direction, i.e. a horizontal shift in demand. This is shown graphically in Figure 1.

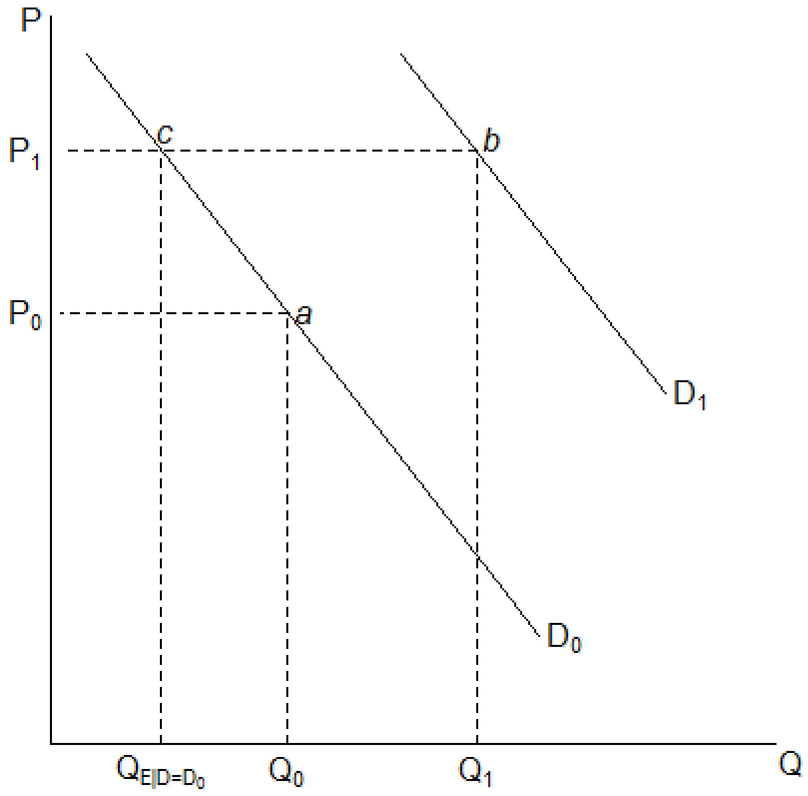

Figure 1. Horizontal shift in demand between two periods

In figure 1, D_0 is the demand schedule for period *0*, and D_1 is the demand schedule for period *1*. P_0 and Q_0 are equilibrium price and quantity in period *0*, and P_1 and Q_1 are equilibrium price and quantity in period *1*. If demand had not changed from period *0* to period 1, a price of P_1 would cause quantity demanded to be $Q_{E\,|\,D=D_0}$.

The absolute horizontal demand shift is equal to the difference between the expected quantity $Q_{E\,|\,D=D_0}$ (in the event of no demand shift) and the observed quantity Q_1. This can be measured by the horizontal distance between point *b* and c in figure 1. The *relative* horizontal shift in demand D_1^H can be specified as follows:

(1) $D_1^H = (Q_1 - Q_{E|D=D_0})/Q_0$

$Q_{E|D=D_0}$ is as of yet unknown. Add and subtract Q_0 to the numerator of equation *(1)* to get:

(2) $D_1^H = \frac{(Q_1 - Q_0) - (Q_{E|D=D_0} - Q_0)}{Q_0}$

Which is simply the difference between the actual and the expected relative change in quantity. The value of the expected quantity change can be determined using the common definition of the price elasticity of demand:

(3) $\eta = \frac{\%\Delta Q}{\%\Delta P} = \frac{(Q_{E|D=D_0} - Q_0)/Q_0}{(P_1 - P_0)/P_0}$

Inserting the observed price change and a predetermined value for the elasticity parameter in *(3)*, the expected quantity change can be estimated as:

(4) $(Q_{E|D=D_0} - Q_0)/Q_0 = \eta \times (P_1 - P_0)/P_0$

Inserting equation *(4)* into equation *(2)*, the demand shift is now expressed as:

(5) $D_1^H = Q_1^* - \eta P_1^*$

Alternatively:

(6) $Q_1^* = \eta P_1^* + D_1^H$

Where asterisks denote relative change throughout the article. Here D_1^{H*}, is the horizontal gross shift in demand from *(1)*, i.e., the shift measured in the quantity direction, which as of yet is caused only by *unknown* demand shifters. The equivalent demand shift measured in the price direction, i.e. the vertical shift, is illustrated in figure 2 below.

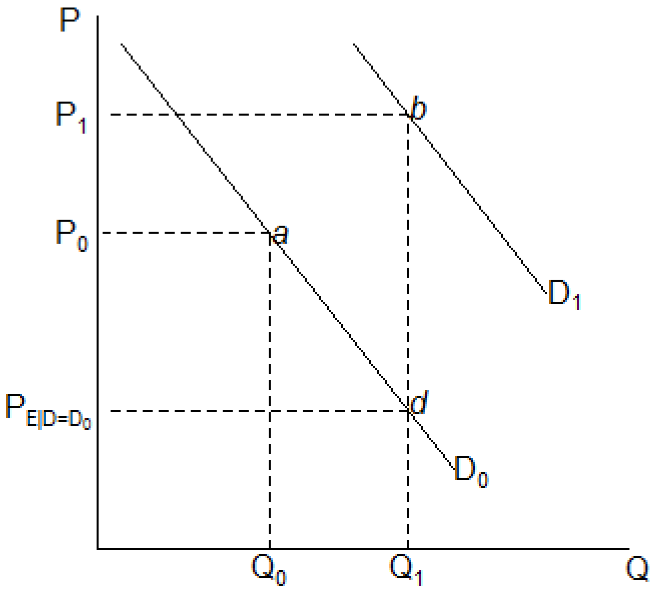

Figure 2. Vertical shift in demand between two periods

For the vertical shift in demand the argument is similar to that of the horizontal shift. Given the observed quantity, Q_1, and assuming that demand has not changed since period *0*, the expected price level in period *1* is defined by $P_{E|D=D_0}$ at point *d* on the demand curve from period *0*. The absolute shift in demand is equal to the difference between the expected price $P_{E|D=D_0}$ and the observed price P_1, or equivalently, between points *b* and *d*. Solving *(6)* for price yields:

(7) $$P_1^* = \frac{Q_1^*}{\eta} - \frac{D_1^H}{\eta}$$

Here $\frac{D_1^H}{-\eta} = D_1^V$ is the vertical shift in demand. The vertical shift in demand is equal to the horizontal shift divided by the negative of the elasticity of demand (Sun & Kinnucan, 2001; M. M. K. Wohlgenant & Lusk, 2011). Muth (p. 223, 1964) describes a vertical shift in demand as "*the relative increase in price at any given quantity on the new demand schedule*". To compute a shift in demand, in either the horizontal or vertical direction, one needs data on price and quantity changes, as well as an appropriate estimate of the elasticity of demand. For any market where price is exogenous to the consumer, quantity is the variable of choice and a horizontal demand shift is the appropriate approach. In a market where quantity is exogenous, computing shifts in demand in the price direction may be the appropriate approach. If neither price nor quantity is exogenous, which at least in the long run is the case for most markets, the choice of computing shifts in demand in the vertical or horizontal direction depends on the purpose of the research, and the development of the market over time. Taking into account the market in question, the elasticities that are used for computing demand shifts are probably more accurate for observed prices and quantities. Hence, for computing shifts in demand in a market with a relatively stable price, but with large shifts in quantities, the horizontal (quantity-oriented) demand shift is likely to be more accurate than a vertical shift. For a market with a large price increase, but not a substantial change in quantities, the vertical demand shifts are probably more accurate. The remainder of the article will focus on the horizontal shift, as quantity purchased is the choice variable for most consumers, and our application is on a market with large growth in quantities and relatively stable prices.

3. **Decomposing the demand shift**

The shift in demand as defined in the previous section can be interpreted as the total shift in demand between two periods, in Asche, Gordon, Trollvik, & Aandahl (2011) referred to as the gross demand shift. D_1^H in equation (6) is interpreted as the combined impact of all variables affecting the demand for a product. By purging the effects of specific variables from the gross (or total) shift in demand, the demand impact of each variable of interest may be computed, as well as the size of the remaining shift in demand caused by unknowns. Consider the general demand equation:

$$(8) \qquad Q = f(P, Z)$$

Where P is price and Z is a vector of *all* variables affecting demand. To evaluate the effects on demand we totally differentiate (8) and convert the partial derivatives to elasticities to yield:

$$(9) \qquad Q^* = \eta P^* + \Psi Z^*$$

Where η is the own-price elasticity of demand, and from (6) we see that $\Psi Z^* = D_1^H$ is the total horizontal shift in demand, where $\Psi = \frac{dQ}{dZ}\frac{Z}{Q}$ is a vector of elasticities corresponding to the variables in Z. The impacts of all variables for which data and appropriate elasticity parameters are obtainable can be disentangled from ΨZ^*. For instance, if data on changes in income Y and a substitute price P_j as well as appropriate elasticity parameters are available, equation (8) can be re-written as:

$$(10) \qquad Q^* = \eta P^* + \eta_Y Y^* + \eta_j P_j^* + \widetilde{\Psi} \tilde{Z}^*$$

where η_Y and η_j are elasticities of income Y and substitute price P_j. $\widetilde{\Psi}$ and $\tilde{Z}^*$ contain all elasticities and corresponding variables other than those of income Y and substitute price P_j. Defining $\widetilde{U} = \widetilde{\Psi}\tilde{Z}^*$ as a demand shift caused by unknowns, we rewrite the expression as:

(11) $$Q^* = \eta P^* + \eta_Y Y^* + \eta_j P_j^* + \widetilde{U}$$

Solving for $\widetilde{U}$ in *(11)* yields:

(12) $$\widetilde{U} = Q^* - \eta P^* - \eta_Y Y^* - \eta_j P_j^*$$

Where $D_1^H = Q^* - \eta P^*$ is the gross shift in demand, $\eta_Y Y^*$ accounts for the demand shift due to income change, and $\eta_j P_j^*$ accounts for the demand shift due to a change in substitute price P_j. Calculating and subtracting the impact of changes in substitute price and income from the gross demand shift gives us the size of the demand shift caused by unknowns $(\widetilde{U})$. Given available data and elasticity parameters for other known factors such as demographics or advertising, additional variables can be introduced.

Figure 3 below illustrates the procedure of disentangling the gross shift in demand.

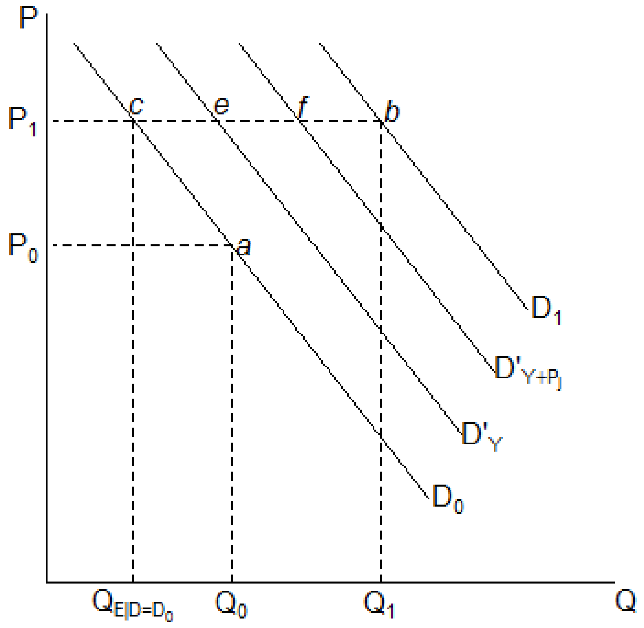

Figure 3. Disentangling horizontal shifts in demand between two periods

In figure 3, the impact of income change and the price of a substitute product are purged from the gross demand shift. The (absolute) gross demand shift is still the horizontal distance between demand schedules D_0 and D_1. This shift is now split into three parts. The impact from a change in income Y on demand is taken into account by the new demand schedule D'_Y. Adding the impact of a shift in substitute price P_j gives the demand schedule D'_{Y+P_j}. The demand shift due to income change is the distance between D_0 and D'_Y, measured by the distance between points *c* and *e*. The demand shift due to a change in the substitute price is the distance between D'_Y and D'_{Y+P_j}, measured by the distance between points *e* and *f*. What remains is the distance between D'_{Y+P_j} and D_1, or between points *f* and *b* in figure 3. The distance between *f* and *b* is caused by other factors than income and substitute prices, and referred to as the effect of *unknowns.*

The equivalent vertical shifts in demand are retrieved in the same way as with the gross shift in demand in the previous section. To get the corresponding vertical shifts in demand divide each component of the horizontal demand shifts by the negative of the own price elasticity η.

In our example, the total demand shift is now split into three parts: the impact of income change, change in the price of a substitute product, and the impact of unknowns. To compute these effects one need data on each variable, as well as appropriate elasticity parameters.

4. An application to salmon markets

Global farmed salmon production has increased from a few thousand tons in 1980 to over 2 million tons in 2013. Initially, this development was possible due to strong productivity growth, and real prices declined by two thirds from the early 1980s to the mid-1990s, as reducing price was an important factor in attracting new consumers (Asche and Bjørndal, 2011). In this process the market expanded to become global (Asche, Bremnes and Wessells, 1999). While the EU, US and Japan have traditionally been the largest markets for salmon, Brazil, Russia and East Asia have experienced enormous growth in consumption since the early 2000s. Main producers are Norway and Chile, who together with Canada, UK, Ireland and the Faroe Islands constitute about 98 % of global salmon production (Brækkan, 2014).

As illustrated in figure 4, from the late 1990s prices have been relatively stable despite rapidly increasing production, indicating substantial demand growth. Previous literature has found that the global market for salmon is integrated (Asche, 2001), and that the law of one price holds (Asche, 2001).

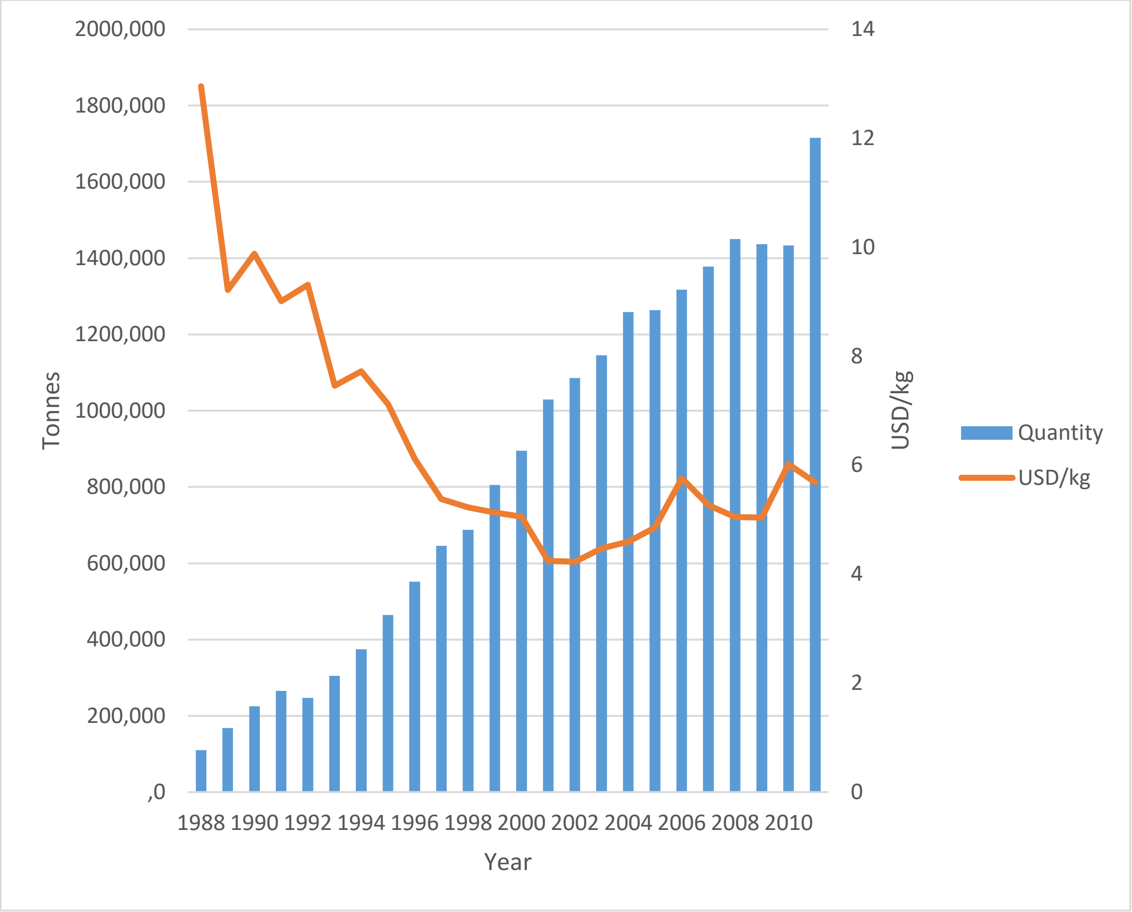

Figure 4. Quantity and real price of farmed salmon in USD/kg 1988-2011

Marsh' (2003) approach for measuring total demand shifts has also been applied to farmed salmon markets (Asche et al., 2011; Brækkan & Thyholdt, 2014). Results show substantial demand growth in most regions since the early 2000s, with large variation both between regions and within regions over time.

For the global salmon market it is far from obvious that the traditional economic variables are the main drivers of demand growth. Main causes of demand growth have been attributed to the geographical expansion of supermarkets and an increasing number of value-added products (Asche & Bjørndal, 2011), but no effort has been undertaken to quantify the effect of these factors. Given the lack of available data on supermarket penetration or value-added products this is not surprising. To overcome the issue of unavailable data the usual approach has been to include time trends to account for structural changes over time (see e.g. Xie and Myrland 2011; Asheim, Dahl, Kumbhakar, Oglend, et al. 2011; Xie, Kinnucan, and Myrland 2008; Asche 1996; Asche, Bjørndal, and Salvanes 1998).

In our application on the salmon market we decompose the yearly regional total demand shifts between factors caused by known knowns (income and substitute prices) and the combined impact of known unknowns (the supermarket revolution and the proliferation of value added products) and unknown unknowns (unidentified causes of demand shifts).

5. Data

We use annual trade data for salmon imports for the period 2002-2011, presented in table A-1 in the appendix, to the main market regions for farmed salmon where there is little or no own production – the EU, the U.S., Japan, Brazil, Russia as well as Rest of the World (ROW)[3]. For ROW, we aggregate the data for all other salmon-importing countries. Data is made available by the Norwegian Seafood Council (personal communication, May 03, 2014). Unit prices are computed and expressed in local currencies for each importing region except for ROW where we use the average world price measured in USD. Quantity is expressed as Live Weight Equivalents (LWE). Since consumers will alter their consumption by smaller amounts if income change is perceived as temporary rather than permanent (Hall & Mishkin, 1982), we use total household consumption as a proxy for permanent income, in line with Friedman's (1957) permanent income hypothesis. Household consumption data are retrieved from Eurostat for the EU (Eurostat, 2018), and the World Bank database for all other regions (The World Bank, 2015). Changes in income are expressed as nominal changes in total household

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[3] Because we use import data we are not able to account for changes in domestic supply from salmon production in consuming countries. US produces a small share of its consumption domestically, while UK and Ireland produces a relatively large share of its own production. For this reason we limit our focus on the EU to the EU in continental Europe, where there is almost no own production of salmon. All references to the EU throughout the article refer to the continental EU.

consumption measured in local currency units, thus also encompassing the impacts of population growth on demand for salmon.

The use of import data implies that we estimate changes in import demand. The reason we use import data is two-fold; first, because a number of demand studies have been carried out using trade data, and hence many of the estimated demand elasticities in the literature are import demand elasticities (Asche et al., 1998; Asche, 1996; Muhammad & Jones, 2011). Second, trade data is readily available over a number of years, for a number of different markets. We have not been able to obtain long data series at the consumer level for the regions we investigate.

Demand analyses of salmon have not identified any clear substitutes for salmon. It appears that salmon have not been chosen in favor of one specific product, but have instead taken small market shares from a large number of products (Asche & Bjørndal, 2011). For that reason, we use regional food price indices from FAO as proxy variables for changes in substitute prices in each market (Food and Agriculture Organization of the United Nations Statistics Division, 2015). Considering salmon constitutes a very small share of total food consumption, the impact of changing salmon prices on the food price indices is most likely negligible. For ROW, we use the world food price index from FAO.

6. Elasticity parameters and operationalization

The annual impact of unknowns is computed as follows:

$$(12') \quad \widetilde{U}_i = Q_i^* - \eta_{i,}P_i^* - \eta_{i,Y}Y_i^* - \eta_{i,j}P_{i,j}^* \qquad i = EU, US, JA, BR, RU, ROW$$

To compute a shift in demand we need appropriate values for the elasticities of demand, substitution and income in each region. In regions where estimates of relevant elasticities have been reported in previous studies, we set the elasticity parameters to the mean of reported values. For markets where there are no published estimates based on recent data, we use the mean of reported elasticities from the literature on salmon demand in various markets. The elasticity estimates we rely on to compute demand shifts are of course subject to potential bias caused by omitted variables such as those mentioned previously. However, they are likely to be more accurate than any elasticity values we could have estimated ourselves given the available data.

In most of the literature where income elasticities for salmon are reported these elasticities are expenditure elasticities conditional on total expenditures *M* on a group of fish commodities. In this study we are evaluating the impact of changes in total income on salmon demand, not the impact from a change in total expenditure on fish. To get the unconditional expenditure elasticity of salmon, or income elasticity $\eta_{i,Y}$, we have to take into account the impact of an income change on total expenditure of fish. Manser (1976) provides an approach for estimating the unconditional expenditure elasticity. To get the income elasticity, multiply the conditional expenditure elasticity for salmon $\eta_{i,\mathrm{M}}$ by the elasticity of demand for fish with respect to total income $\eta_{i,fish,\mathrm{Y}}$. The income elasticity of salmon in region *i* is then given by:

$$(13) \qquad \eta_{i,Y} = \frac{\partial \mathrm{Q_i}}{\partial \mathrm{Y_i}}\frac{\mathrm{Y_i}}{\mathrm{Q_i}} = \frac{\partial \mathrm{Q_i}}{\partial \mathrm{M_i}}\frac{\mathrm{M_i}}{\mathrm{Q_i}}\frac{\partial \mathrm{M_i}}{\partial \mathrm{Y_i}}\frac{\mathrm{Y_i}}{\mathrm{M_i}} = \eta_{\mathrm{i,M}} \times \eta_{\mathrm{i,fish,Y}}$$

Where Q is quantity of salmon, Y is total income, and M is total expenditure on the fish commodities of which the conditional expenditure elasticity of salmon $\eta_{\mathrm{i,M}}$ is computed. For all regions but Japan[4], as a proxy for $\eta_{fish,\mathrm{Y}}$ we use the results for unconditional expenditure elasticities for fish from a cross-country analysis of demand for various food

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[4] For Japan, we use elasticity values from (Sakai et al., 2009) where they estimate $\eta_{\mathrm{i,fish,Y}}$ with regards to the conditional elasticity $\eta_{\mathrm{i,M}}$, and compute $\eta_{i,Y}$ following the same procedure as in this article.

groups by Muhammad, Seale, Meade, & Regmi (2011). The elasticities of substitution are retrieved from the homogeneity assumption that the sum of all elasticities should be zero. The elasticity parameters are reported in table *1*.

Table 1. Elasticity parameters

Region/Elasticity	η_i	$\eta_{i,Y} = \eta_{i,M} \times \eta_{i,fish,Y}$	$\eta_{i,j}$[a]
The EU	-1.01[b]	0.45 = 1.22[d] × 0.37[f]	0.56
The U.S.	-0.99[c]	0.27 = 1.04[d] × 0.26[f]	0.72
Japan	-1.5[d]	1.1 = 2.08[c] × 0.53[d]	0.4
Brazil	-0.95[e]	0.7 = 1.22[c] × 0.57[f]	0.25
Russia	-0.95[e]	0.65 = 1.22[c] × 0.53[f]	0.3
ROW	-0.95[e]	0.63 = 1.22[c] × 0.52[f]	0.32

[a] We use the homogeneity restriction to compute cross-price elasticities

[b] Based on reported elasticity values for France, the largest market in the EU, from (Xie & Myrland, 2011)

[c] Based on reported elasticities from (C. Davis, Lin, & Yen, 2007; Jones, Wozniak, & Walters, 2013)

[d] Based on reported elasticities from (Sakai, Yagi, Ariji, Takahara, & Kurokura, 2009)

[e] Based on reported elasticities from (Chidmi, Hanson, & Nguyen, 2012; Davis, Lin, & Yen, 2007; Fousekis & Revell, 2004; Hong & Duc, 2009; Jones, Wozniak, & Walters, 2013; Muhammad & Jones, 2011; Sakai, Yagi, Ariji, Takahara, & Kurokura, 2009; Tiffin & Arnoult, 2010; Xie, Kinnucan, & Myrland, 2009; Xie & Myrland, 2011)

[f] Based on reported elasticities from (Muhammad et al., 2011). For EU we use the estimate for France, which has the highest salmon consumption in in the EU (Asche and Bjørndal, 2011).

We compute global demand shifts caused by unknowns by quantity-weighted aggregation of the demand shifts from each region as follows:

$$(14) \quad \widetilde{U}_{global} = \sum_i^6 k_i \widetilde{U}_i \, , i = EU, US, JA, BR, RU, ROW$$

Where k_i is the quantity share of global imports for each region. The same approach is used to compute global income and substitution effects.

7. Results

We suspect that Mr. Rumsfeld would agree with us that not only unknowns are important; we must also take into account that what we *believe* we do know may be biased by unreliable data, improper analysis, or other things that affect the interpretation of reality. In the context of our analysis, this translates to addressing the sensitivity of our results to the choice of elasticity values. The studies from which the elasticity values are retrieved vary in terms of period investigated, methodology, levels of aggregation of data, frequency of data, and at which level of the value chain the analyses were done. We also observe considerable variation in estimated elasticity values. The accuracy of the chosen elasticities are thus highly uncertain. To take into account this uncertainty, we simulate the results by selecting prior distributions for each elasticity (see e.g. (Brækkan & Thyholdt, 2014; G. C. Davis & Espinoza, 1998; G. C. Davis, 1997; Zhao, Griffiths, Griffith, & Mullen, 2000). We use truncated normal distributions for the own-price elasticities, restricting them to be negative, while we use the standard normal distribution to simulate the income elasticities. The substitution elasticities are in each simulation retrieved from the homogeneity assumption.

Standard errors of the estimated elasticities were never larger than 0.3 in any of the studies where these were reported. However, the demand elasticities reported in the literature range from -0.2 to -1.7, and vary with product form, origin, demographics, and region. We found published estimates of elasticity values for EU, Japan and the US, and choose a standard deviation of 0.3 for these markets. This implies, for instance, that for the -1.5 point estimate of the own-price elasticity of Japan, a standard deviation of 0.3 is equivalent to assuming a 68 per cent probability that the elasticity is between -1.2 and -1.8, and a 95 per cent probability for values between -0.9 and -2.1. Since our point estimates for the elasticities in Brazil, Russia and ROW are based on estimates from other regions, and hence are more uncertain, we set the standard deviations in these markets to 0.5. The means used for the simulation are our point estimates reported in table 1. All elasticity values are simulated 10,000 times, where we for each simulation compute and decompose the annual regional demand shifts. The means and the 2.5 and 97.5 per cent empirical quantiles of the simulated geometric average annual demand shifts are reported in table 2. Note that we refer to demand shifts caused by changes in income and substitute prices as income and substitution *effects* on demand.

Table 2. Average annual per cent changes in demand

Region	Substitution effect	Income effect	Unknowns	Total shift
EU	**0.86***	**1.32***	**6.86***	**9.11***
	(0.2 , 1.48)	(0.66 , 1.97)	(3.89 , 9.71)	(6.33 , 11.82)
USA	**2.08***	**1.13***	**3.56***	**6.82***
	(1.21 , 2.95)	(0.18 , 2.07)	(1.51 , 5.54)	(4.67 , 8.84)
Japan	**0.09**	**-0.21**	**1.89**	**1.61**
	(-0.21 , 0.38)	(-0.46 , 0.03)	(-0.75 , 4.3)	(-0.88 , 3.96)
Brazil	**2.03**	**8.11***	**12.28***	**22.85***
	(-2.36 , 6.03)	(4.19 , 12)	(4.64 , 19.93)	(14.97 , 30.86)
Russia	**3.54**	**12.22***	**11.02***	**28.01***
	(-1.85 , 8.86)	(5.49 , 18.83)	(4.85 , 16.9)	(23.28 , 33)
ROW	**2.44**	**4.87***	**11.32***	**19.06***
	(-0.97 , 5.88)	(2.05 , 7.85)	(7.65 , 14.95)	(15.83 , 22.46)
Global	**1.54***	**2.37***	**6.75***	**10.73***
	(0.86 , 2.23)	(1.71 , 3.02)	(5.07 , 8.42)	(9.11 , 12.32)

Notes: Numbers in bold are 50 % empirical quantiles. Numbers in parantheses are 2.5 and 97.5 % empirical quantiles. * indicates that the estimate is significantly different from zero at $\alpha = 0.05$.

In all regions except Russia the effect of unknowns is the largest component of the total shift in demand. The average effect of unknowns is significantly different from zero in all regions except Japan. This corroborates our argument that unknowns are important components of the growth in salmon demand throughout the world. When comparing regions we observe that the contribution of unknowns is larger in emerging markets Brazil, Russia and ROW, which is not surprising given the current status of the literature; almost all research on demand for salmon deals with industrialized regions like the EU, US or Japan, and there is little knowledge about emerging markets (Kuo & Chuang, 2016). Limited access to data may be one explanation, it could also be that fast growth makes it difficult to accurately estimate the sources of changes in these markets.

Another important topic is how stable the unknowns are over time. If the effect of unknowns is predictable over time, a time trend could adequately capture this. To determine the stability of the unknowns, we examine how they vary from year to year. Table 3 reports the results from the simulated yearly effects of unknowns.

Table 3. Empirical quantiles for yearly effect of unknowns

Year	EU	US	Japan	Brazil	Russia	ROW	Global
2003	**1.0**	**8.9***	**-15.9***	**11.9**	**15.7***	**-2.8**	**2.5**
	(-6.7 , 8.4)	(3.7 , 14)	(-17.1 , -14.6)	(-10.4 , 38.4)	(4.1 , 26.9)	(-8.5 , 2.8)	(-1.6 , 6.5)
2004	**5.6***	**-6.2***	**19.0***	**29.3***	**28.3***	**12.7***	**4.4***
	(2.7 , 8.5)	(-9.3 , -3)	(18.6 , 19.5)	(21 , 37.2)	(9.8 , 46.4)	(7.8 , 17.5)	(2.5 , 6.3)
2005	**16.9***	**3.9***	**3.0**	**-21.3***	**45.4***	**31.4***	**14.1***
	(6.7 , 26.6)	(0.4 , 7.5)	(-3.4 , 9.3)	(-37.1 , -6.6)	(33.9 , 57.3)	(26.5 , 36.7)	(8.9 , 19.3)
2006	**18.0***	**22.3***	**32.8***	**38.6***	**-22.1***	**35.6***	**19.7***
	(5.7 , 29.7)	(6.9 , 37.4)	(12.6 , 52.7)	(7.7 , 75.5)	(-36.6 , -6.9)	(21.8 , 52)	(12.2 , 27.2)
2007	**-6.8**	**0.4**	**-14.5***	**9.6**	**4.8**	**6.9**	**-2.7**
	(-16.9 , 3.1)	(-0.5 , 1.2)	(-15.9 , -13.2)	(-9.4 , 26.3)	(-24.3 , 31)	(-7.1 , 18.7)	(-8 , 2.7)
2008	**-2.0**	**-9.6***	**-4.5**	**46.9***	**-13.4***	**-2.3**	**-3.6**
	(-8.3 , 4.3)	(-14.2 , -5.1)	(-10.1 , 1.2)	(8.9 , 79.2)	(-25 , -3.7)	(-16.2 , 9.4)	(-7.7 , 0.3)
2009	**11.8***	**-5.6***	**-21.3***	**20.1***	**32.2***	**12.6**	**8.4***
	(7.5 , 16.1)	(-7.7 , -3.6)	(-28.7 , -13.6)	(3 , 39.4)	(17.2 , 49.3)	(0.7 , 24.3)	(5.4 , 11.4)
2010	**28.4***	**3.3**	**9.9**	**-9.3**	**34.9***	**5.6**	**18.1***
	(12.8 , 43.9)	(-4.9 , 11.3)	(-0.7 , 20.6)	(-32.8 , 18.6)	(27.2 , 43.9)	(-5.9 , 19.3)	(9.7 , 26.4)
2011	**-5.0**	**19.7***	**22.8***	**6.4**	**-2.9**	**9.6**	**3.0**
	(-11.6 , 1.4)	(17.7 , 21.8)	(19.9 , 25.8)	(-11.4 , 21.2)	(-26.3 , 17.6)	(-1 , 18.6)	(-1.2 , 7.1)

Notes: Numbers in bold are 50 per cent empirical quantiles. Numbers in parantheses are 2.5 and 97.5 per cent empirical quantiles. * indicates that the estimate is significantly different from zero at $\alpha = 0.05$.

For all regions we find significant effects of unknowns in three or more years. In the USA, Japan, Brazil and Russia we find both significant positive and negative unknowns throughout the period. The ranges of the 50 per cent empirical quantiles of the unknowns are between 32 and 68 per cent in each region, and 23 per cent globally. In Brazil, a market characterized by a large growth in salmon consumption, the effect of unknowns vary between -21 and 47 percent. The unsystematic behavior of unknowns indicate that using time trends to capture unknown causes of demand change will miss substantial variation.

To gauge the relative importance of each demand shifter on global demand growth over time, we calculate the cumulative global demand growth using point estimates of the elasticity values as reported in table 1. Figure 5 illustrates the cumulative gross global demand growth from 2002 to 2011, and the relative effect of each component. The cumulative effect of unknowns $\widetilde{U}_{global,t}^{cum}$ in year *t* is estimated as follows

$$\widetilde{U}_{global,t}^{cum} = \prod_{t=2002}^{2011} (1 + \widetilde{U}_{global,t}) - 1$$

The same approach is used to compute the income, substitution and total demand shift.

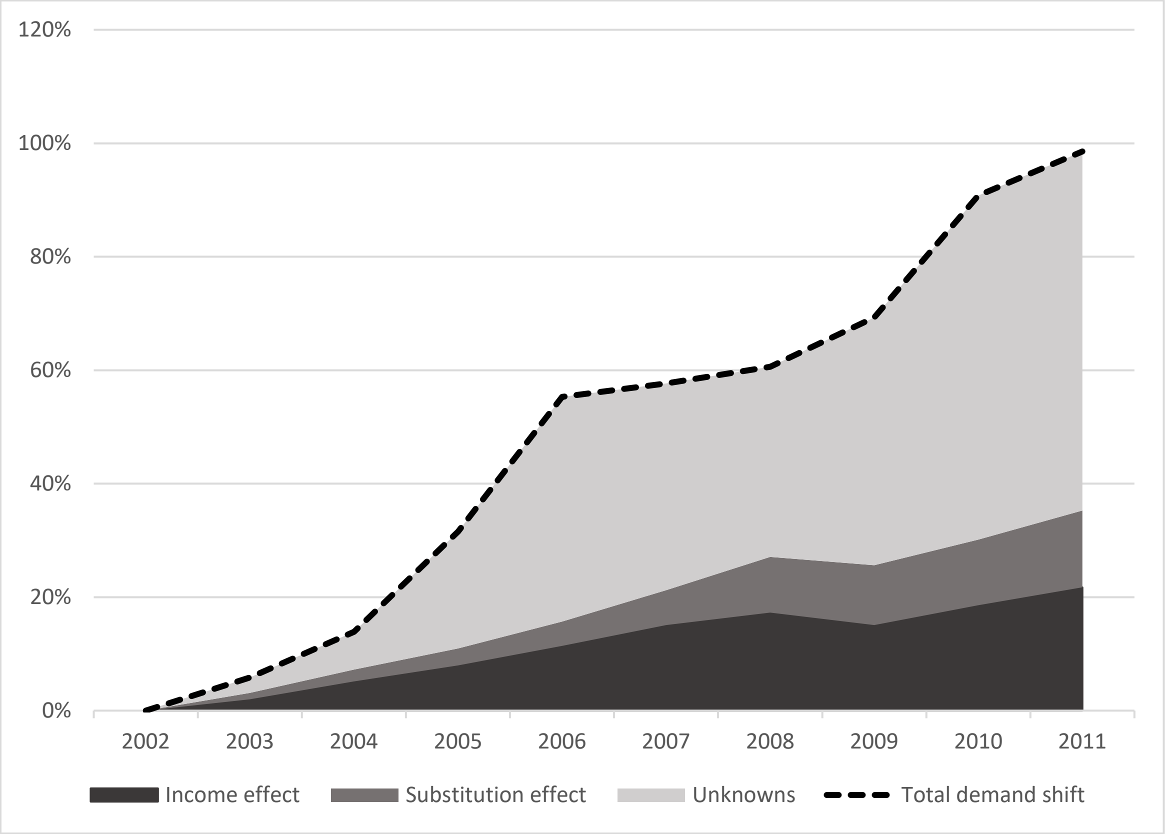

Figure 5. Cumulative gross global demand shift components

As can be observed in figure 5, of a total global demand growth of almost 100 percent from 2002 to 2011, more than 60 percent is due to unknowns, while around 22 percent is due to income growth, and around 14 percent is due to substitution effects. Note in Figure 1 the price increase from 2002 to 2011, which explains why the net increase in quantity throughout the period is smaller than the estimated increase in demand.

8. Concluding remarks

Donald Rumsfeld states in unambiguous fashion that there are in fact things we do not know, which he refers to as unknowns. In classical demand analysis it is common to address unknowns by adding trend terms, which can be appropriate if unknown impacts on demand are relatively smooth over time. We argue, however, that demand shifts caused by unknowns may not always be as smooth as usually assumed. This article provides an alternative to the use of trend indicators to quantify unknowns over time. We start our procedure by extending an approach by Purcell (1998) for computing the gross (total) demand shift between two periods. As long as data and appropriate elasticity values are available, the demand impact of any variable of interest can also be computed. The impact of unknowns on demand is determined by disentangling the impacts of specific economic factors such as prices and income from the total demand shift.

We apply the procedure on an annual basis to the largest markets for farmed salmon. We find that effects of unknowns vary considerably both between regions and within regions over time, contributing to large variation in demand growth between years. Unknowns account for more than half of the cumulative gross demand growth globally and in all but one region.

The results indicate that more than half of demand growth in the global salmon markets is in essence a “black box” of unknown content. So how can salmon market analysts go forward with this? A natural next step would be to try and identify key factors which could contribute to reducing the size of unknown demand shifts, and of course try to get access to data to these key factors. The suspects are numerous; changes in market margins and logistics between farm and retail level, growth in supermarket concentration, increasing number of product varieties, health and food safety concerns among consumers, changes in trade conditions, changing demographics, and probably several others. While a thorough investigation of sources behinds unknown demand shifts is beyond the scope of this paper, our results can hopefully serve as a useful starting point for further research on global salmon demand.

While the lack of available data may often be a hindrance to determining the causes of demand shifts, it is important not only to focus on what we know, but also to determine and acknowledge the relative importance of what we do not know. Our results show that unknowns are by far the most important contributors to demand growth in the global salmon market. We suspect this is also the case for many other commodities, especially in markets characterized by substantial changes in quantities or prices.

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Appendix

Table A-1. Background data

Year	P EU (EUR)	P U.S. (USD)	P Japan (JPY)	P Brazil (BRL)	P Russia (RUB)	P ROW (USD)
2002	3.47	4.48	473	6.12	86.9	3.38
2003	3.07	4.94	482	8.99	90.2	3.66
2004	3.17	4.89	484	8.83	94.8	3.86
2005	3.70	5.23	527	7.83	106	4.22
2006	4.50	6.73	709	10.6	126	5.16
2007	3.84	6.92	695	9.32	104	4.85
2008	3.67	6.80	651	6.91	115	4.84
2009	3.92	6.98	570	8.67	142	4.80
2010	5.01	7.98	672	11.6	174	5.84
2011	4.57	8.53	636	10.5	150	5.68
Year	**Q EU**	**Q US**	**Q Japan**	**Q Brazil**	**Q Russia**	**Q ROW**
2002	410908	272025	65340	15404	22346	73182
2003	470999	276464	52637	12756	28859	71905
2004	489463	273801	62712	17772	41903	83921
2005	498994	275169	56466	17569	64796	108077
2006	493542	267454	46285	19456	49594	129975
2007	547839	272005	41156	25687	69319	159188
2008	586783	263308	43331	47212	69000	171880
2009	610580	243876	40725	49306	78811	194918
2010	624335	220894	34195	34116	98952	179830
2011	663731	258330	44517	42843	121573	217760

Year	**FPI EU**	**FPI US**	**FPI Japan**	**FPI Brazil**	**FPI Russia**	**FPI ROW**
2002	105.37	105.01	98.6	117.01	136.05	107.95
2003	106.48	107.27	98.4	140.83	151.29	114.28
2004	106.43	110.97	99.3	146.47	166.9	121.53
2005	106.7	113.65	97.8	150.98	189.67	127.19
2006	108.51	116.33	98.29	151.01	207.75	134.32
2007	110.95	120.93	98.58	161.25	226.45	144.55
2008	117.53	127.6	101.13	182.29	273.69	163.5
2009	117.2	129.89	101.32	192.87	290.38	174.24
2010	118.32	130.89	101.03	204.63	327.85	187.11
2011	121.01	135.78	100.62	222.73	361.68	202.95

Year	**HHC EU (EUR)**	**HHC US (USD)**	**HHC Japan (JPY)**	**HHC Brazil (BRL)**	**HHC Russia (RUB)**	**HHC ROW (USD)**
2002	20756.66	912.06	870.69	289038.30	5541.67	7385.30
2003	23097.40	1052.76	902.57	287514.20	6692.30	7764.30
2004	25704.72	1160.61	937.37	288599.30	8588.10	8257.80
2005	27668.82	1294.23	977.69	291132.60	10792.30	8790.40
2006	29632.20	1428.91	1020.03	293433.30	13129.30	9297.50
2007	33004.32	1594.07	1065.94	294122.00	16217.60	9744.50
2008	35914.27	1786.84	1099.65	292055.40	20183.60	10005.50
2009	34682.36	1979.75	1095.66	282941.70	21202.90	9842.90
2010	37371.65	2248.63	1125.08	285867.10	23843.30	10201.90
2011	41038.79	2499.49	1155.26	284244.30	27192.50	10711.80

P = average annual price in local currency per kg Raw Weight Equivalent. Currency in parentheses (Source: Norwegian Seafood Council)

Q = annual import quantity in metric tons, Raw Weight Equivalents (Source: Norwegian Seafood Council)

FPI = Food price index (Source: FAO)

HHC = Total household consumption in local currency, in billions. Currency in parentheses (Sources: World Bank database, except from the EU where data is from Eurostat)