MODELLING OF MILK PURCHASE PRICE IN ESTONIA

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ABSTRACT. *Milk purchase price is an essential indicator which characterises the situation in dairy sector. The primary objective of the present study was the creation of an experimental econometric model of milk purchase price in Estonia. The model was created using the macro-econometric model for the Estonian dairy sector, which outlines the linkage between the milk purchase price and input factors: cheese and butter prices in the European market and barley price in Estonian market. Nonlinear equations (Cobb-Douglas function) enable to analyse the formation of milk purchase price in detail. The stochastic equations are estimated by full information maximum likelihood (FIML) method. The equations were estimated using data from 1992 to 2008 inclusive. The parameters of structural equation of milk purchase price have theoretically consistent signs and are significant. Projections for the milk purchase price are run out over a five-year period. Using the isoprice curves, the impacts of an increase in the price of cheese, price of butter and price of barley to milk purchase price are evaluated. The possible substitution values between two different inputs (price of cheese, price of butter and price of barely in different combinations) are evaluated. Some results from those evaluations are then presented. Perspective implementation of milk purchase price model is discussed. The milk purchase price model for the Estonian agriculture may be used for projection and analysis purposes.*

Keywords: *Dairy sector, milk purchase price, macro-economic modelling, simultaneous equations, isoprice curve*

Introduction

The European Union (EU) dairy sector is facing a period of significant changes due to enlargement, the Luxembourg reform and ongoing World Trade Organisation (WTO) trade liberalisation negotiations. The entry of ten new member states in 2004 and two more in 2007 has increased both the production capacity and the demand for dairy products in the EU.

Enlargement, domestic policy reforms and trade liberalisation all affect the EU dairy sector.

The new member states present a number of challenges to the successful modelling of the agricultural sector. The milk sector across the EU differs considerably between EU member states. Differences exist in terms of milk production systems (pasture, feed grain and hybrid systems), production costs (land, labour and other inputs) and milk utilisation (fresh products, specialist food ingredients and basic commodities).

Previous studies have analysed their separate impacts on the dairy sector. For example, the impact of further trade liberalisation was studied by Larivie`re and Meilke (1999), Cox *et al*. (1999), Shaw and Love (2001) and Donnellan and Westhoff (2002). INRA-Wageningen Consortium (2002) developed an in-depth study of dairy sector reform proposals in preparation for the Luxembourg reform. The impacts of this reform were then analysed by, among others, Binfield *et al*. (2003) and Bouamra-Mechemache *et al*. (2003). Studies of the impact of EU enlargement on the dairy sector include Banse and Grethe (2005).

Estonia is one of the new members of the European Union. The EU enlargement means for East European countries a lot of changes in their agriculture. These changes are at the political, economical and technical level. This means that information systems on agriculture (databases, models etc) have to move along with those changes. Consequently, the economic models in Estonia have either to be created, developed or renewed, and must be harmonised with the European requirements. The created models should enable to analyse the current situation and develop predictions for different political decisions in EU and Estonia. Hopefully, we can use new information technology to lead such evolutions.

We recognise that there is variation in the behavioural characteristics of the agricultural production systems over time as well as between countries. The diverse nature of agricultural production systems and agri-food markets across the EU poses a challenge to anyone seeking to develop a model that can be used to analyse policy at an EU and member state level.

The guiding principle in constructing the national level commodity models is that the models are first and foremost an economic model, and as such economic theory is our first guide in specifying the models. The economic relationships in the national commodity models are based, in so far as is practicable, on time series econometric estimates of these relationships. Theory and expert judgement is also used in the verification and, if necessary, adjustment of econometrically estimated equations, particularly when used to generate projections.

Improving the competitiveness of agriculture is a priority objective of Estonian agricultural policy. The outcome and impacts of those policy actions will strongly depend on the developments of the world agricultural markets. The dairy is the most competitive sector of Estonian agriculture. Consequently, the need to further improve the competitiveness of the Estonian dairy farms is obvious.

Milk purchase price is an essential indicator which characterises the situation in dairy sector.

The concept of "milk purchase price" has in world dairy literature different nominations. In FAPRI EU GOLD model is used term "the fluid milk price received by farmers". Some authors use term "farm milk price" or "farm gate milk price". Also nomination "raw milk price" is used. While Statistical Yearbook of Estonia uses nomination (term) "milk purchase price", we use that nomination in this paper.

Milk purchase prices are the final outcome of the interaction of supply and demand for hundreds of dairy products in world and domestic markets.

The milk purchase price is very important characteristic for milk producers (farmers) and for milk manufacturers. Milk producers income depend essentially from milk purchase price and milk manufacturers cost of production also depends essentially from milk purchase price. Consequently, using correctly predicted milk purchase price values enables milk producers (farmers) and milk manufacturers to plan their future developments. The milk purchase price is also important characteristic to develop predictions for different political decisions in Estonia.

The objective of this study is the creation of milk purchase price model in the Estonia at the national aggregate level, the estimation the model parameters and analysis of results.

The paper discusses and demonstrates various approaches to agricultural economic modelling, including some of the potential advantages of combining different models into integrated frameworks. A specific objective of the paper is the demonstration, how different model approaches can be combined in order to perform such integrated analyses, and how results from different models can supplement and support each other.

This paper is organized as follows. First, we present a review of literature on modelling purchase milk price and the models are proposed. Next, the results, which were analysed using simultaneous equation modelling, are reported. The final section discusses the findings of the study and concludes the paper.

Models and methods

For modelling milk purchase price different models may be used.

- Regression models;
- Time series models;
- Simultaneous equation (macro-econometric) models etc.

While the data for parameter estimation of macroeconomic models are time series data, and time series for Estonia are short, then regression models and time series models give results with low confidence. Previous studies also assert Greene (2008), that "Intuition would suggest that system methods, 3SLS, GMM, and FIML, are to be preferred to single-equation methods, 2SLS and LIML. Indeed, if the advantage is so transparent, why would one ever use a single-equation estimator. An obvious practical consideration is the computational simplicity of the single-equation methods. But the current state of available software has all but eliminated this advantage."

Since the least-squares estimator is extremely sensitive to outliers, we aim to construct a robust alternative. An overview of strategies to robustify the multivariate regression method is given in Maronna and Yohai (1997) in the context of simultaneous equations models.

Therefore in this paper simultaneous equation (macro-econometric) model is used.

We at the Estonian University of Life Sciences (Department of Business Informatics and Econometrics) have investigated the possibilities implementing simultaneous equation (macroeconomic) models in Estonian agriculture. The results of investigations are published in many papers and conference theses (Põldaru *et al.,* 2006; Põldaru *et al*., 2007; Põldaru *et al*., 2008).

The modelling methodology employed in this paper follows closely that which has been used by FAPRI for many years with great success (Hanrahan, 2001). This also facilitates the use of world and EU projections to be utilised by the Estonian model (Binfield *et al.,* 2000). At present, a small country assumption is used for Estonia, which can be justified given its relatively small size (Donnellan *et al*., 2002).

The FAPRI system is a dynamic, partial equilibrium, global model (Hanrahan, 2001). As a partial equilibrium model, macroeconomic factors such as population, real GDP per capita, GDP deflator, GDP growth, and growth rates for the general economy, and various manufacturing producer price indices are exogenous to the system.

Figure 1 shows how the Estonian dairy model successive components (endogenous variables, key relationships) link with one other. Most essential endogenous variable in Figure 1 is purchase price of milk. The purchase price of milk has twofold role in the model. First, the milk purchase price depends from prices of cheese, butter, SMP, WMP and other variables and, second, milk purchase price influence the production, consumption, export and import of cheese, butter, SMP and WMP.

The Estonian dairy model consists of 41 equations – 23 stochastic equations and 18 identities. Stochastic equations are estimated from the historical data. Identities are equations that hold by definition; they are always true. There are 41 endogenous variables, 42 exogenous variables and many lagged endogenous and lagged exogenous variables.

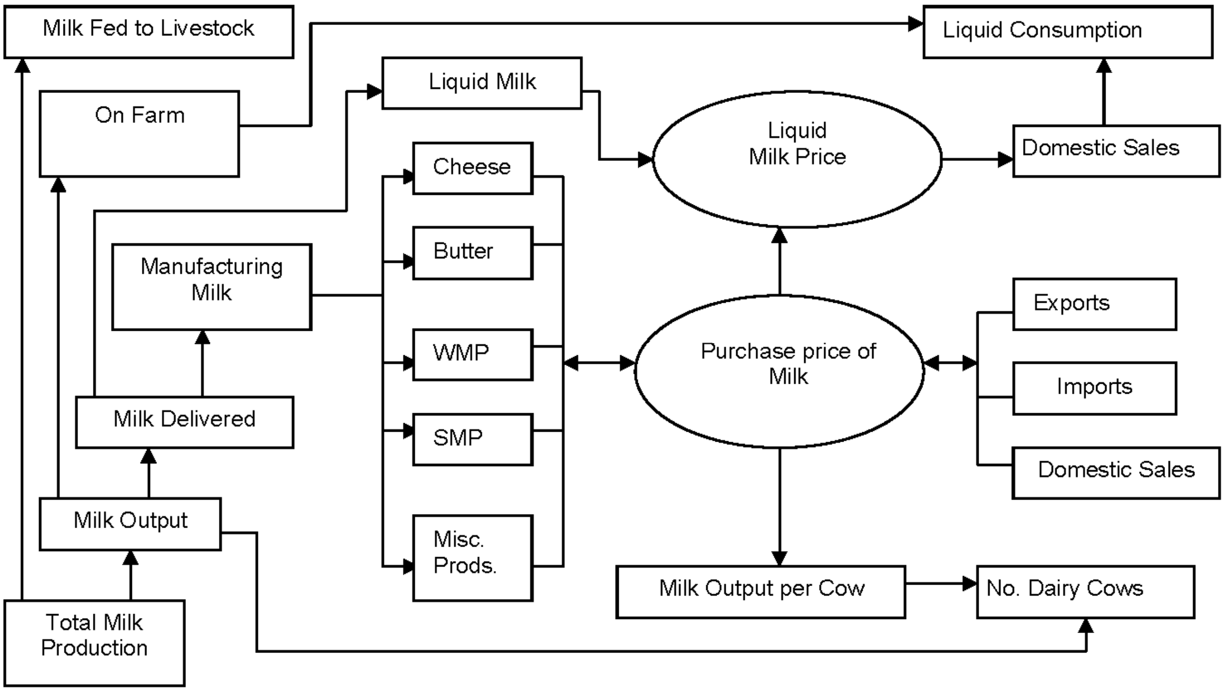

Figure 1. *Flow diagram showing key relationships in the dairy sector model*

The dairy model equations are estimated econometrically using historical data from 1992 to 2009 inclusive and are then solved simultaneously.

The stochastic equations are estimated by full information maximum likelihood method (FIML). The stochastic equations are log-linear or constant elasticity models.

The Fair-Parke program (Fair *et al*., 2003) was used for the estimation of dairy model parameters.

Results and discussion

Overview of milk production in Estonia

Next we discuss the dynamics of milk purchase price in Estonia. The time series data of milk purchase price over the last 19 years in the Estonia provided in Figure 2.

Figure 2 shows that there has been substantial rise in milk purchase price in Estonia during the years 1992–2008. When in 1992 the milk purchase price was 0.08 € per kg, then by 2008 the milk purchase price had risen to 0.30 € per kg (the change has been more than three-fold compared with 1992). The average milk purchase price in EU was 0.33 € per kg in 2007. So the milk purchase price in Estonia has approached the EU average milk purchase price. For that reason it is important to analyse the factors influencing the milk purchase price.

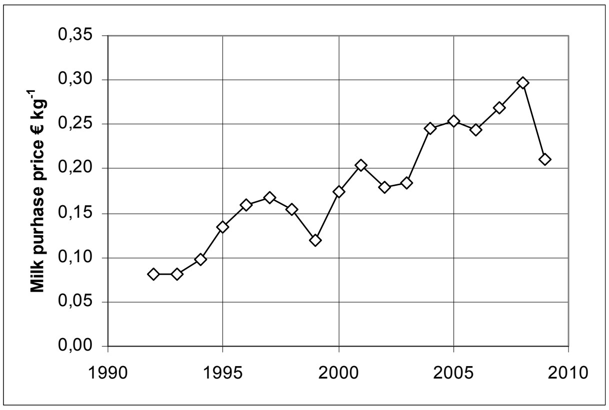

Figure 2*. Milk purchase price in Estonia, 1992–2009*

For the purpose of discussing markets and prices, it is useful to separate dairy products into fluid and manufactured categories.

The time series data of raw milk use over the last 19 years in the Estonia is provided in Figure 3. This shows that fraction of manufactured products is changing.

In 1992–1997 fluid milk and cream took only about 20% of the milk supply. The relatively high share of manufactured products was due to the intensive export of dairy products to Russia in those years. In 1998–2001 the share of manufactured products diminished to 60%. In those years the Estonian dairy sector was hit by the collapse of the lucrative Russian market. In 2002–2005 the share of manufactured products was relatively invariable on the level of 65%. In 2006–2007 the share of manufactured products diminished to 54%. In those years the Estonian powders production and export diminished substantially.

It should be mentioned, that milk utilization noted here is based on the accounting the amount of milk in dairy products using the butterfat content of the products.

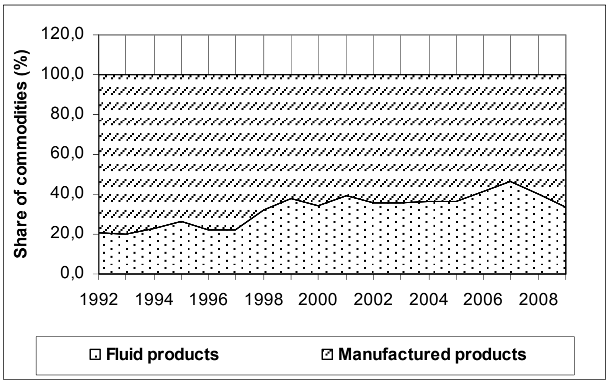

***Figure 3**. Share of different commodities (fluid and manufactured products) in Estonian dairy sector, 1992–2009*

For the purpose of discussing markets and prices, it is useful to separate dairy products into domestic use and export categories.

Next we discuss the share of export of different manufactured product category (Figure 4).

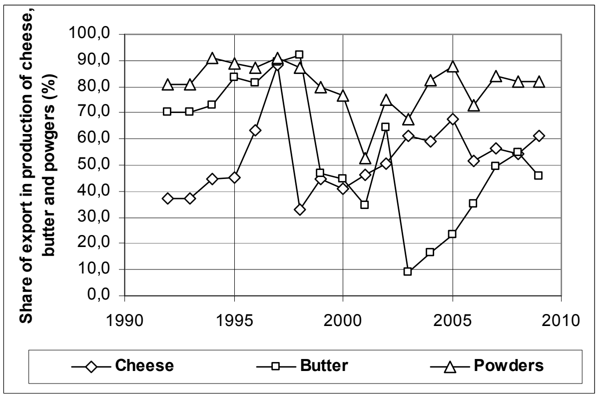

***Figure 4.** Share of export in production of cheese, butter and powders, 1992–2009*

The proportion of exported powders has the highest value. In 1992–1999 the export of powders took about 80–90% of the powder production. In next years the proportion of powders used for export has gone down and diminished to 50% in 2001. From this time onward the proportion of powder export increased and in 2003–2009 took about 80% of powder production.

Analogously varies the proportion of butter export. In 1992–1998 the export of butter took about 70–90% of the butter production. In next years the proportion of butter used for export has gone down substantially and diminished to 10% in 2003. From this time onward the proportion of butter export steadily increased and in 2008 took 55% of butter production.

In 1992–2009 the proportion of cheese export varied on a smaller scale than proportion of powders and butter. In 2002–2009 the export of cheese took about 50–60% of the cheese production.

Summarising the discussion on proportions of export in production of different dairy products it should be concluded, that export of dairy products is an essential factor for Estonian dairy sector.

Consequently, developments in export markets, including prices of cheese, butter and powders in those markets have an essential influence on Estonian dairy sector including to milk purchase price in Estonia.

Milk purchase price model

Based on the simultaneous equation analysis, the equation presented in the paper was the most reliable, where the independent variables were price of cheese (x_1) and price of butter (x_2) in EU, and barley purchase price (x_3) in Estonia.

The last version of milk purchase price mode is log-linear or constant elasticity model. In the model logs of dependent variable are regressed on logs of exploratory variables. The equation is equal to

$$LN\left(Y\right) = -1{,}053 + 0{,}361 \cdot LN\left(x_1\right) + 0{,}216 \cdot LN\left(x_2\right) + 0{,}728 \cdot LN\left(x_3\right) \quad (1),$$

where
x_1 – price of cheese € per kg,
x_2 – price of butter € per kg,
x_3 – price of barely € per kg.

As Figure 5 illustrates, for the period of 1992 to 2008 the time series values and the projected value of milk purchase price did not differ substantially. The coefficient of determination for equation of milk purchase price was relatively high – 0.635. Consequently, the milk purchase price projections based on the mentioned equation, characterised the real milk purchase price changes during the analysed period comparatively well.

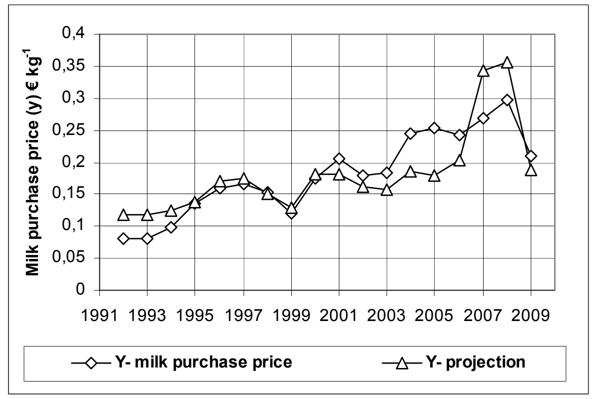

Figure 5. *Time series data of milk purchase price (y) and projections of that variable*

Next we analyse the behaviour of milk purchase price depending on the parameters of the model. For that purpose the isoprice curves were used.

In economics, an isoprice curve (line) (derived from price and the Greek word iso, meaning equal) is a contour line drawn through the set of points at which the same output price is formed while changing the quantities of two or more inputs. Isoprices are analogous to isoquants, which are typically drawn on capital-labor graphs, showing the tradeoff between capital and labor in the production function, and the decreasing marginal returns of both inputs. In the case of isoprices the graphs are drawn on two inputs x_1 and x_2, showing the tradeoff between inputs x_1 and x_2 in the price function. Adding one input while holding the other constant eventually leads to decreasing marginal output, and this is reflected in the shape of the isoprice. A family of isoprice curves can be represented by an isoprice map, a graph combining a number of isoprice curves, each representing a different quantity of output.

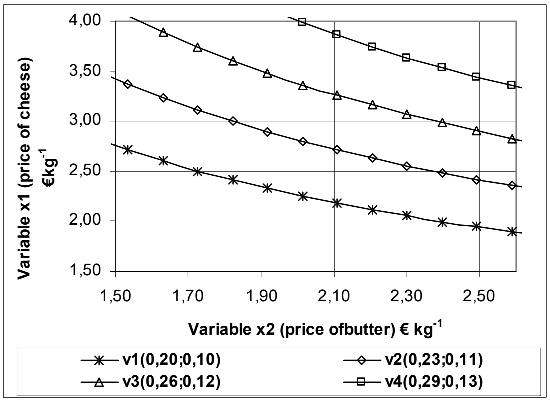

***Figure 6**. Isoprice curves of variables x_1 – price of cheese and x_2 – price of butter (for different milk purchase price level and for different price of barely), where the first number in the parentheses indicates the value of milk purchase price and the second the value of price of barely for different variants*

Figure 6 shows that for the maximal level of milk purchase price – 0.29 € per kg (v4 (0.29;0.13)) the price of barley should have value 0.13 € per kg and the price of cheese varies in the interval 3.40–4.00 € per kg and the price of butter varies in the interval 2.00–2.70 € per kg. Hence, at the maximal level of milk purchase price, the potential range (variability) of price of cheese (0.6 € per kg) and the potential range of price of butter (0.7 € per kg) are practically the same.

For the minimal level of milk purchase price – 0.20 € per kg (v1 (0.20;0.10)) the price of barley should have value 0.10 € per kg and the price of cheese varies in the interval 1.90–2.70 € per kg and the price of butter varies in the interval 1.50–2.70 € per kg. Hence, at the minimal level of milk purchase price the potential range of price of cheese (0.8 € per kg) and the potential range of price of butter (0.8 € per kg) are also the same.

Consequently, the substitution rate of prices of cheese and butter in milk purchase model is practically the same.

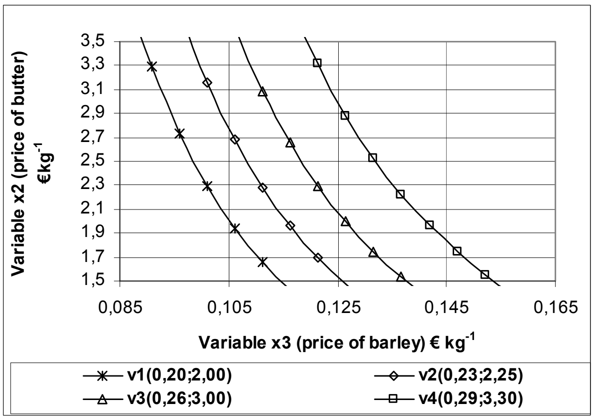

***Figure 7**. Isoprice curves of variables x_2 – price of butter and x_3 – price of barely (for different milk purchase price level and for different price of cheese), where the first number in the parentheses indicates the value of milk purchase price and the second the value of price of cheese for different variants*

Figure 7 shows that for the maximal level of milk purchase price – 0.29 € per kg (v4 (0.29;3.30)) the price of cheese should have value 3.30 € per kg and the price of butter varies in the interval 1.50–3.50 € per kg and the price of barley varies in the interval 1.12–1.53 € per kg. Hence, at the maximal level of milk purchase price, the potential range of price of butter (2.0 € per kg) and the potential range of price of barley (0,033 € per kg) are essentially different. Thereby the price of barley changed in small quantity.

For the minimal level of milk purchase price – 0.20 € per kg (v1 (0.20;2.00)) the price of cheese should have value 2.00 € per kg and the price of butter varies in the interval 1.50–3.50 € per kg and the price of barley varies in the interval 0.089–0.115 € per kg. Hence, at the minimal level of milk purchase price the potential range of price of butter (2.00 € per kg) and the potential range of price of barley (0.026 € per kg) are also essentially different. Thereby the price of barley changed slightly.

Consequently, the substitution rates of prices of butter and barley are essentially different compared the previous case. In the present case the price of barley has considerable impact on milk purchase price. A relatively modest change in the price of barley causes the transition to next isoprice curve.

Figure 8 shows that for the maximal level of milk purchase price – 0.29 € per kg (v4(0.29;2.50)) the price of butter should have value 2.50 € per kg and the price of cheese varies in the interval 1.50–4.00 € per kg and the price of barley varies in the interval 0.122–0.185 € per kg. Hence, at the maximal level of milk purchase price, the potential range of price of butter (2.5 € per kg) and the potential range of price of barley (0,063 € per kg) are essentially different. Thereby the price of barley did not change much.

For the minimal level of milk purchase price – 0.20 € per kg (v1(0.20;1.25)) the price of butter should have value 1.25 € per kg and the price of cheese varies in the interval 1.50–4.00 € per kg and the price of barley varies in the interval 0.089–0.137 € per kg. Hence, at the minimal level of milk purchase price the potential range of price of butter (2.50 € per kg) and the potential range of price of barley (0.048 € per kg) are also essentially different. Thereby the price of barley changed a little.

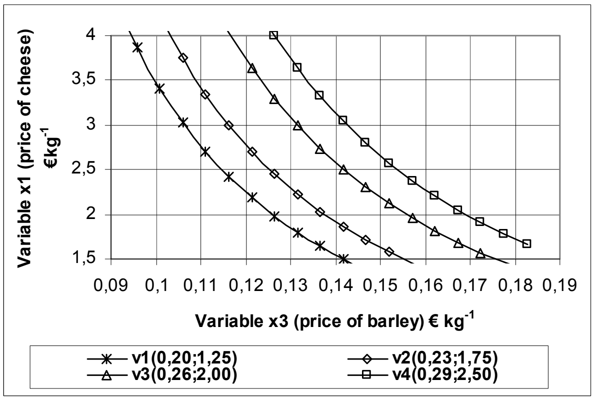

Figure 8. *Isoprice lines (curves) of variables x_1 – price of cheese and x_3 – price of barely (for different milk purchase price level an for different price of butter), where the first number in the parentheses indicates the value of milk purchase price and the second the value of price of butter for different variants*

Let us next discuss the possible use of isoprice lines or isoprice map.

Isoprice maps may be implemented to test the milk purchase price model's capability for work in critical (extreme) situations. Using isoprice maps we considered two extreme situations: in 2008 the milk purchase price was maximal in February 2008 – 0.35 € per kg and dropped very sharply to 0.19 € per kg in July 2009.

As an example on an isoprice map (Figure 9) are presented all possible values of independent variables (x_1, x_2, x_3) of milk price model (for the case y = 0.35). Let us consider the possible use of that map.

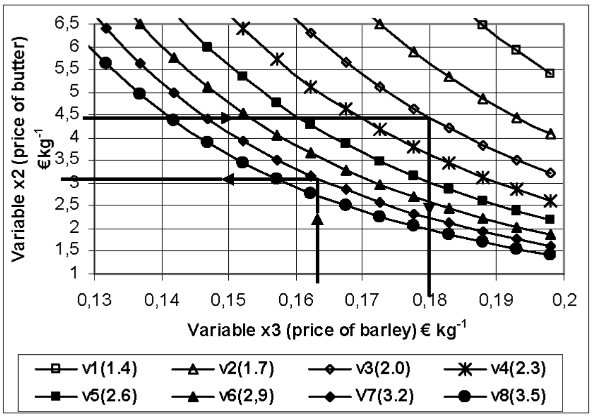

Figure 9. *Isoprice lines (curves) of variables x_2 – price of butter and x_3 – price of barely (for constant milk purchase price – 0.35 € per kg and for different price of cheese), where the number in the parentheses indicates the value of price of cheese for different variants*

Figure 9 shows isoprice map of variables x_2 – price of butter and x_3 – price of barely (for 8 different values of price of cheese), where for different variants the number in the parentheses indicates the value of price of cheese in € per kg. The isoprice value is the same for all 8 variants – 0.35 € per kg.

In 2008 the predicted milk purchase price has maximal value – 0.35 € per kg. On the isoprice map (Figure 9) are presented all possible values of independent variables (x_1, x_2, x_3) of milk price model (for the isoprice value y = 0.35). The real values of the independent variables are following: x_1= 3.20, x_2=2.50 and x_3=0.163 Let us consider some examples.

In the fist case let us proceed from price of barley. The price of barely is equal to 0.163 € per kg. Further, select on the x-axis (Figure 9) the value 0.163 and move to the desired isoprice line. Arrows on the graph indicate the moving path. The price of cheese equals to 3.20 € per kg. Consequently, in that case we should move to the appropriate variant v7 (3.2). Further, moving from the selected isoprice line to y-axis, we conclude that the price of butter should be 3.07 € per kg.

In the second case let us proceed from price of butter. Suppose that the price of butter is equal to 4.5 € per kg. Further, select on the y-axis (Figure 9) the value 4.5 and move to the desired isoprice line. Arrows on the graph indicate the moving path. Suppose that the price of cheese equals to 2.0 € per kg. Consequently, in that case we should move to the appropriate variant v3(2.0). Further, moving from the selected isoprice line to x-axis, we conclude that the price of barely should be – 0.18 € per kg

Consequently, milk purchase price – 0.35 € per kg may be formed in different combinations of independent variables, and isoprice map enables to analyse different variants in detail.

Analogous isoprice maps may me constructed and analysed for different desired values of milk purchase price.

Conclusions

Summarising the results it should be concluded:

- Macroeconomic modelling provide a new approach to the economic analysis.
- An experimental econometric milk purchase price model for the Estonian agriculture was created.
- The milk purchase price model may be used for projection and analysis purposes.
- Nonlinear equations (Cobb-Douglas function) enable to analyse the formation of milk purchase price in detail.
- In order to insure a survival of the system, a partial methodological improvement as well as a systematic validation of the model is necessary.
- Systems estimators are used where economic theory suggests they are necessary or advantageous.
- Of course any modelling exercise is an ongoing evolutionary process, which is also seen in the current Estonian dairy model.

In conclusion, it should be mentioned that to ensure the competitiveness of the milk sector, economists should constantly observe the economic changes, and compose and renew the econometric models to assure the theoretical and practical usability of the different models.

The obvious advantage in this model is that it allows Estonian researchers to interact with the FAPRI World and EU models and to get the modelling experience.

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Piima kokkuostuhinna modelleerimine Eestis

R. Põldaru, T. Roosmaa, J. Roots

Kokkuvõte

Antud artiklis käsitletakse piima kokkuostuhinna mudeli koostamist Eesti piimandussektori makroökonomeetrilise mudeli baasil. Artiklis antakse lühiülevaade Eesti piimandussektori makroökonomeetrilisest mudelist, mille üheks oluliseks võrrandiks on piima kokkuostuhinna võrrand. Analüüs näitas, et piima kokkuostuhind Eestis sõltub eelkõige juustu, või ja pulbrite hinnast maailmaturul. Üksikasjalikult on analüüsitud piima kokkuostuhinna võrrandit, mille sõltumatuteks muutujateks on juustu ja või maailmaturu- hind ning odra kokkuostuhind Eesti siseturul. Modelleerimiseks kasutati Cobb-Douglase funktsiooni. Mudeli parameetrite hindamiseks kasutatud andmestik hõlmas ajavahemikku 1992–2009. Mudeli parameetrite leidmiseks on kasutatud tarkvarapaketti Fair-Parke Program. Mudeli usaldusväärsuse ja kasutamisvõimaluste iseloomustamiseks on koostatud ja analüüsitud sõltumatute muutujate asendusgraafikuid (samahinnajooni). Analüüs näitas, et mudel kirjeldab usaldusväärselt piima kokkuostuhinna kujunemist Eesti siseturul ning mudeli abil on võimalik prognoosida piima kokkuostuhinna kujunemist tulevikus ja välja selgitada erinevate sõltumatute muutujate mõju piima kokkuostuhinna kujunemisele.