Quantity Formulation vs. Price Formulation and Assessment of the Minimum Price Policy in the Tunisian Dairy Sector

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Abstract*: The objectives of this article are to develop a partial equilibrium model for a dairy sector according to two approaches—"Quantity Formulation" and "Price Formulation"—and to show their equivalence under the assumption of perfect competition. We introduce the spatial dimension to present the"Price Formulation" approach of models developed by Bouamra et al. (1998) and Abbassi et al. (2008) .We illustrate theoretically and numerically how to incorporate the minimum price policy at the farm level for the Tunisian dairy sector according to the Price Formulation approach. We analysed two scenarios of removal of minimum price policy that differ according to the values of farm supply elasticity. The simulation results show that producers stand to lose between 78.6 and 127.8 million Dinars in surplus depending on the value of farm supply elasticity. Permit holders' rent would also decrease between 0.8 and 1.3 million Dinars. However, consumers' surplus is predicted to increase between 67.8 and 110.1 million Dinars compared with the baseline solution. The overall welfare implications of removal of minimum price policy are negative and range between 13.3 and 18.2 million Dinars.*

Keywords: minimum price policy, dairy sector, partial equilibrium model, price formulation, quantity formulation.

JEL-Classification:L66, C6, Q13

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1 Introduction

After signing GATT agreements and the free trade agreement with the European Union (EU), Tunisia opened its borders to the free exchange of industrial goods. However, despite broad trade liberalisation pressures, agriculture and food sectors are still highly protected, especially the dairy sector. In this context, Tunisian public authorities have often used border protection measures aiming at protecting local products from foreign competition, promoting dairy product consumption, ensuring food security and mainly supporting raw milk producers' income. The dairy policy in Tunisia is based on four measures: (i) price control for farm-based raw milk production by a guaranteed minimum price system, (ii) subsidies for collection and refrigeration in collection centres, (iii) subsidies for milk for consumer consumption and (iv), a high border protection measures for most imported dairy products including a tariff rates quota (TRQ) for butter and cheese. Under TRQ, a small quantity of a product (minimum access) can be imported at a minimum tariff (intra-quota tariff), whereas imports that exceed the quantity permitted by minimum access to the market are subject to a higher, often prohibitive tariff.[1]

[1]Others countries also use the TRQ system. For example, Canada protects its markets from import competition in the egg, poultry and dairy sectors by imposing a minimum tariff on foreign imports as long as they are less than or equal to the commitments made under the North American Free Trade Agreement (NAFTA) and WTO (See the website of Foreign Affairs, Trade and Development Canada at http://www.international.gc.ca/controls-controles/prod/agri/index.aspx?menu_id=3. Accessed September 4, 2015). In its latest evaluation of the European Union trade policy, the WTO reported that in 2010, the European Union had notified 112 tariff rate quotas in the agricultural sector, 34 of which were completely filled, and 10 were between 80% and 99% filled (WTO, 2013b). In the United States, this mechanism is used in the dairy (See the USDA website at: http://www.fas.usda.gov/itp/imports/usdairy.asp. Accessed September 4, 2015) and sugar (See the USDA website at http://www.fas.usda.gov/itp/imports/ussugar.asp. Accessed September 4, 2015) sectors.

On April 18, 2016 the first round of the EU-Tunisia negotiations on the Deep and Comprehensive Free Trade Area (DCFTA) was launched.[2] The negotiations covered many fields, notably free trade of agricultural products and services. Spécifically, for the Tunisian dairy sector, trade liberalisation threatens the ability to control prices on the local market and the possibility of supporting producers through the minimum price policy.

The objective of this paper is to evaluate the market impacts of removal of a minimum price policy in the Tunisian dairy sector. Partial equilibrium models (PEM) are commonly used by modellers to analyse economic policiesin several fields, particularly agri-food, energy, and international trade. These models are developed according to two approaches. The first one is the Quantity Formulation (QF) aslo defined as a primal approach. Particularly for the dairy sector, studies have commonly used this approach. Kawaguchi, Suzuki and Kaiser (1997) developed a partial equilibrium model for the Japanese dairy sector. Their model consists in maximising an adjusted welfare function defined as the sum of dairy producers' and buyers' surplus, under resource allocation constraints. Cox and Chavas (2001) built a spatial partial equilibrium model representing the US dairy sector to evaluate price discrimination policies. Bouamra-Mechemache et al. (2002a, 2002b) studied the effect of agricultural policy instruments in the European dairy sector using a spatial partial equilibrium model linking EU countries with the rest of the world. Abbassi et al. (2008) analysed the impact of free trade in the Canadian dairy industry from a spatial partial equilibrium model.[3] The theoretical model maximises an objective function, defined as the total surplus in the Canadian dairy sector, subject to

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[2]See at http://trade.ec.europa.eu/doclib/press/index.cfm?id=1380. Accessed June 29, 2016.

[3]Other recents exemples of the primal approach are Nolte (2010) and Bouamra-Mechemache, Jongeneel and Réquillart (2008).

resource allocation constraints. However, in some cases the QF approach does not allow to model all the sector characteristics.To illustrate, Abbassi et al. (2008) have imposed a constraint on butter and milk powder production that takes into consideration the price support scheme. This constraint does not hold after the liberalisation scenario. New constraints on butter and milk powder production are required for the support prices to hold. Thus, to improve the modelling of price policies on the input market (farm milk) or the output market (dairy products), a model with a price formulation (PF), a dual approach, stated in terms of prices instead of quantities should be developed.

In this paper, we develop a partial equilibrium model for the Tunisian dairy industry using the dual approach (PF approach) and compare it to the QF partial equilibrium model (Abbassi et al., 2008; Bouamara-Mechemache et al., 2002a, 2002b; Cox and Chavas, 2001). Our models incorporate domestic policies i.e. producers' prices support and subsidies to milk collection centers and trade policy i.e. TRQ and *ad-valorem* tariffs. We demonstrate that the PF approach is equivalent to the QF approach. This result is important because the PF approach is simpler and more suitable for the implementation of price policies on the input or the output market. Our second contribution consists in illustrating the PF approach numerically for the Tunisian dairy sector to evaluate the minimum price policy at the farm level. The results obtained contribute to the debate regarding the potential impact of the Comprehensive Free Trade Area (DCFTA) in negociation between EU and Tunisia.

The rest of the paper is organised as follows. Section 2 presents mathematical formulations and shows that equilibrium conditions derived from the QF and PF approaches are equivalent. In section3, we model the Tunisian dairy sector with the price formulation approach and we report the welfare impacts of removal of the minimum price policy. A sensitivity analysis of farm supply elasticity is discussed. Lastly, section 4 presents the conclusion and economic implications.

2 Quantity formulation versus price formulation

Tunisian dairy industry is characterized by the raw milk as the only primary product with dairy components i.e. lipids and proteins, which contribute to the production of final products. At the retail level, we assume that there are seven dairy products: fresh milk, concentrated milk, butter, cheese, yogurt, fermented milk and ice cream. Let *K* and *S* represent, respectively, the number of processed products and the number of milk components. At the farm level, we assume a quadratic cost function: $CT\left(Q^m\right) = a^m Q^m + 0.5 b^m {Q^m}^2$ where Q^m represents farm-level milk production. The parameters a^m and b^m are strictly positive parameters. The variable *Tr* represents the quantity of raw milk collected in the milk collection centers:

$$Tr \leq Q^m \qquad (1)$$

The condition (1) implies that the quantity of collected milk is lower than or equal to the quantity produced at the farm level. We assume a constant marginal cost of milk collection c^m. There is a subsidy for the milk collection centers, denoted by Sb^m. The subsidy contributes to reducing the unit cost of milk collection.

The quantity of component *s* in raw milk used by processing firms must be greater than the quantity of the same component in the production of all processed products (denoted Q_k^o):

$$\sum_k b_{s,k} Q_k^o \leq a_s Tr,\ \forall s \in S \qquad (2)$$

where the coefficient a_s measures the quantity of component *s* per unit of raw milk and $b_{s,k}$ denotes the quantity of component *s* per unit of product *k*. It is assumed that the cost function associated with production of good *k* is linear, and thus $C_k\left(Q_k^o\right) = G_k Q_k^o,\ \forall k \in K$ with G_k being the marginal cost.

Let $P_k^d\left(Q_k^d\right)=a_k^d-b_k^d Q_k^d,\ \forall k \in K$ be the buyers' inverse demand function for product *k*. Consumption of dairy product *k* in region *i* is measured by Q_k^d. The parameters a_k^d and b_k^d are strictly positive. Dairy processors sale T_k units of dairy product k, while respecting the following constraint:

$$T_k \leq Q_k^o,\ \forall k \in K \qquad (3)$$

The dairy trade policy in Tunisia includes a tariff-rate quota for butter and cheese. Let the variable M_k^{uc} represents the quantity imported under the Minimum Access Commitment (MAC), $\overline{M}_k$, with an in-quota tariff denoted by t_k^{uc}. The imports under the MAC must not exceed $\overline{M}_k$:

$$M_k^{uc} \leq \overline{M}_k, \forall k \in K \qquad (4)$$

M_k^{oc} measures the imports exceeding the MAC with an over-quota tariff, t_k^{oc}. Moreover, the local demand (Q_k^d) must not be lower than total supply (including imports):

$$Q_k^d \leq T_k + M_k^{uc} + M_k^{oc},\ \forall k \in K \qquad (5)$$

2.1 The quantity formulation approach

The optimisation problem, according to the QF approach, consists in maximising the total surplus in the dairy sector subject to resource allocation constraints (Samuelson, 1952; Takayama and Judge, 1971). World prices and transport costs of product *k* with the rest of the world are respectively represented by $p_{w,k}$ and $c_{w,k}$. The objective function is:

$$W=\sum_{k\in K}\left(\int_0^{Q_k^d} p_k^d(q_k)dq_k\right)-CT\left(Q^m\right)-\left(c^m-sb^m\right)Tr-\sum_{k\in K}C_k\left(Q_k^o\right)$$
$$-\sum_{k\in K}\left(p_{w,k}+c_{w,k}+t_k^{uc}\right)M_k^{uc}-\sum_{k\in K}\left(p_{w,k}+c_{w,k}+t_k^{oc}\right)M_k^{oc} \qquad (6)$$

The welfare function W defined by (6) is equal to the consumer'surplus $\left(\sum_{k\in K}\int_0^{Q_k^d} P_k^d(q_k)dq_k\right)$ minus the costs at the farm, collection and processing levels $\left(CT\left(Q^m\right)+\left(c^m-sb^m\right)Tr+\sum_k C_k\left(Q_k^o\right)\right)$ and the value of imports under MAC $\left(\sum_{k\in K}\left(p_{w,k}+c_{w,k}+t_k^{uc}\right)M_k^{uc}\right)$ and those over MAC $\left(\sum_{k\in K}\left(p_{w,k}+c_{w,k}+t_k^{oc}\right)M_k^{oc}\right)$. The Lagrangean defined by the objective function in (6) under the resource allocation constraints is written as follows:

$$L=\sum_{k\in K}\left[\int_0^{Q_k^d}\left(a_k^d-b_k^d q_k\right)dq_k\right]-a^mQ^m+0.5b^m{Q^m}^2-\left(c^m-Sb^m\right)Tr-\sum_{k\in K}G_kQ_k^o+p^m\left[Q^m-Tr\right]$$
$$+\sum_{s\in S}pc_s\left[a_sTr-\sum_{k\in K}b_{s,k}Q_k^o\right]+\sum_{k\in K}p_k^o\left[Q_k^o-T_k\right]+\sum_{k\in K}p_k^d\left[T_k+M_k^{uc}+M_k^{oc}-Q_k^d\right]$$
$$+\sum_{k\in K}\gamma_k\left(\overline{M}_k-M_k^{uc}\right)$$

Where $pc_s\geq 0,\ p_k^o\geq 0,\ \gamma_k\geq,\ p_k^d\geq 0$ and $p^m\geq 0$ represent the multipliers associated to different constraints of the optimization problem. The price offarm milk is noted by p^m. The multiplier associated to the allocation constraint of dairy components is noted by pc_s which represents the price of a component unit s in raw milk. Whereas p_k^o and p_k^d represent respectively the supply and demand prices of a dairy product k. The multiplier γ_k represents the import licence rent of product *k*. The Kuhn-Tucker conditions can be represented as the mixed complementarity conditions below:

$$\frac{\partial L}{\partial Q_k^o} \le 0 \perp Q_k^o \ge 0 \Leftrightarrow p_k^o - \sum_{s\in S}\left[b_{s,k} pc_s\right] - G_k \le 0 \perp Q_k^o \ge 0, \forall k \in K \tag{7}$$

$$\frac{\partial L}{\partial Q_k^d} \le 0 \perp Q_k^d \ge 0 \Leftrightarrow a_k^d - b_k^d Q_k^d - p_k^d \le 0 \perp Q_k^d \ge 0, \forall k \in K \tag{8}$$

$$\frac{\partial L}{\partial T_k} \le 0 \perp T_k \ge 0 \Leftrightarrow p_k^d - p_k^o \le 0 \perp T_k \ge 0, \forall k \in K \tag{9}$$

$$\frac{\partial L}{\partial Tr} \le 0 \perp Tr \ge 0 \Leftrightarrow \sum_{s\in S} pc_s a_s - c^m + sb^m - p^m \le 0 \perp Tr \ge 0 \tag{10}$$

$$\frac{\partial L}{\partial M_k^{uc}} \le 0 \perp M_k^{uc} \ge 0 \Leftrightarrow p_k^d - \gamma_k - \left(p_{w,k} + c_{w,k} + t_k^{uc}\right) \le 0 \perp M_k^{uc} \ge 0, \forall k \in K \tag{11}$$

$$\frac{\partial L}{\partial M_k^{oc}} \le 0 \perp M_k^{oc} \ge 0 \Leftrightarrow p_k^d - \left(p_{w,k} + c_{w,k} + t_k^{oc}\right) \le 0 \perp M_k^{oc} \ge 0, \forall k \in K \tag{12}$$

$$\frac{\partial L}{\partial Q^m} \le 0 \perp Q^m \ge 0 \Leftrightarrow p^m - \left(a^m + b^m Q^m\right) \le 0 \perp Q^m \ge 0 \tag{13}$$

$$\frac{\partial L}{\partial p_k^o} \ge 0 \perp p_k^o \ge 0 \Leftrightarrow Q_k^o - T_k \ge 0 \perp p_k^o \ge 0, \forall k \in K \tag{14}$$

$$\frac{\partial L}{\partial p_k^d} \ge 0 \perp p_k^d \ge 0 \Leftrightarrow T_k + M_k^{uc} + M_k^{oc} - Q_k^d \ge 0 \perp p_k^d \ge 0, \forall k \in K \tag{15}$$

$$\frac{\partial L}{\partial \gamma_k} \ge 0 \perp \gamma_k \ge 0 \Leftrightarrow \overline{M}_k - M_k^{uc} \ge 0 \perp \gamma_k \ge 0, \forall k \in K \tag{16}$$

$$\frac{\partial L}{\partial p^m} \ge 0 \perp p^m \ge 0 \Leftrightarrow Q^m - Tr \ge 0 \perp p^m \ge 0 \tag{17}$$

$$\frac{\partial L}{\partial pc_s} \ge 0 \perp pc_s \ge 0 \Leftrightarrow a_k Tr - \sum_{k\in K} b_{k,s} Q_k^o \ge 0 \perp pc_s \ge 0, \forall s \in S \tag{18}$$

The model according to QF is based on a system composed of 12 inequations with 12 endogenous variables. The system is entirely identified and it is possible to derive solutions for the endogenous variables of the model.

2.2 The price formulation approach

To adequately model price policies, the PF approach must be developed for the partial equilibrium model. The PF is stated in terms of prices instead of quantities. The supply raw milk function and demand function of dairy products are expressed in terms of prices as follows:

$$Q^m\left(p^m\right)=\frac{-a^m}{b^m}+\frac{1}{b^m}p^m \qquad (19)$$

$$Q_k^d\left(p_k^d\right)=\frac{a_k^d}{b_k^d}-\frac{p_k^d}{b_k^d},\forall k\in K \quad (20)$$

There is an additional constraint specifically associated with the minimum price policy in the model: $p^m \geq p_{\min}$. To define the objective function of the model according to the PF approach we adopt the approach used by Kalvelagen (2003) in the definition of the objective function, which differs from the approach used by Devadoss (2013).[4] The objective function is therefore written as:

$$\Theta=\int_0^{p^m} Q^m\left(p\right)dp-\int_0^{p_k^d} Q_k^d\left(p\right)dp+\gamma_k \overline{M}_k \quad (21)$$

The optimisation problem according to the PF approach consists in minimising the objective function defined by (21) under the price constraints:

[4]Devadoss (2013) proposes a primal approach that maximises the net social monetary gain function instead of the quasi-welafare function (refers to welfare function in (6)). To obtain the dual formulations, the quantity-dependent demand and supply functions are substituted into the primal Lagrangian to yield the dual objective function. According to the approach of Devadoss (2013), the derivation of the dual objective function is very lengthy.

$$
\begin{cases}
\min_{p^m, p_k^d, p_k^d, \gamma_k, pc_s} \Theta = \int_0^{p^m} Q^m(p)dp - \int_0^{p_k^d} Q_k^d\left(\overline{p}\right)d\overline{p} + \gamma_k \overline{M}_k \\
S.C \\
p_k^d \le p_k^o, \forall k \in K \\
p_k^d \le p_{w,k} + \gamma_k + c_{w,k} + t_k^{uc}, \forall k \in K \\
p_k^d \le p_{w,k} + c_{w,k} + t_k^{oc}, \forall k \in K \\
p_k^o \le \sum_{s \in S} b_{s,k} pc_s + G_k, \forall k \in K \\
p_{\min} \le p^m \\
\sum_{s \in S} a_s pc_s \le p^m + c^m - Sb^m, \forall s \in S
\end{cases}
$$

The Lagrangean expression is written as follows:

$$
\begin{aligned}
L = & \int_0^{p^m} Q^m(p)dp - \int_0^{p_k^d} Q_k^d\left(\overline{p}\right)d\overline{p} + \gamma_k \overline{M}_k + \sum_{k \in K} T_k\left(p_k^d - p_k^o\right) \\
& + \sum_{k \in K} M_k^{uc}\left(p_k^d - p_{w,k} - \gamma_k - c_{w,k} - t_k^{uc}\right) + \sum_{k \in K} M_k^{oc}\left(p_k^d - p_{w,k} - c_{w,k} - t_k^{oc}\right) \\
& + \sum_{k \in K} Q_k^o\left(p_k^o - \sum_{s \in S} b_{s,k} pc_s - G_k\right) + v\left(p_{\min} - p^m\right) + Tr\left(\sum_{s \in S} a_s pc_s - p^m - c^m + Sb^m\right)
\end{aligned}
\tag{22}
$$

According to the PF approach, the quantities $T_k \ge 0,\ M_k^{uc} \ge 0,\ M_k^{oc} \ge 0,\ Q_k^o \ge 0,\ v \ge 0$ and $Tr \ge 0$ represent the multipliers associated with the price constraints. The Kuhn-Tucker conditions can be represented as mixed complementarity conditions:

$$
\frac{\partial L}{\partial p^m} \ge 0 \perp p^m \ge 0 \Leftrightarrow Q^m\left(p^m\right) - Tr \ge 0 \perp p^m \ge 0 \tag{23}
$$

$$
\frac{\partial L}{\partial p_k^d} \ge 0 \perp p_k^d \ge 0 \Leftrightarrow -Q_k^d\left(p_k^d\right) + T_k + M_k^{uc} + M_k^{oc} \ge 0 \perp p_k^d \ge 0, \forall k \in K \tag{24}
$$

$$
\frac{\partial L}{\partial p_k^o} \ge 0 \perp p_k^o \ge 0 \Leftrightarrow -T_k + Q_k^o \ge 0 \perp p_k^o \ge 0, \forall k \in K \tag{25}
$$

$$
\frac{\partial L}{\partial pc_s} \ge 0 \perp pc_s \ge 0 \Leftrightarrow -\sum_{k \in K} b_{k,s} Q_k^o + a_s Tr \ge 0 \perp pc_s \ge 0, \forall s \in S \tag{26}
$$

$$\frac{\partial L}{\partial \gamma_k} \geq 0 \perp \gamma_k \geq 0 \Leftrightarrow \overline{M}_k - MQ_k^{uc} \geq 0 \perp \gamma_k \geq 0, \forall k \in K \tag{27}$$

$$\frac{\partial L}{\partial T_k} \leq 0 \perp T_k \geq 0 \Leftrightarrow p_k^d - p_k^o \leq 0 \perp T_k \geq 0, \forall k \in K \tag{28}$$

$$\frac{\partial L}{\partial Q_k^o} \leq 0 \perp Q_k^o \geq 0, p_k^o - \sum_{s \in S} b_{s,k} pc_s - G_k \leq 0 \perp Q_k^o \geq 0, \forall k \in K \tag{29}$$

$$\frac{\partial L}{\partial v} \leq 0 \perp v \geq 0 \Leftrightarrow p_{\min} - p^m \leq 0 \perp v \geq 0 \tag{30}$$

$$\frac{\partial L}{\partial Tr} \leq 0 \perp Tr \geq 0 \Leftrightarrow \sum_{s \in S} a_s pc_s - p^m - c^m + Sb^m \leq 0 \perp Tr \geq 0 \tag{31}$$

$$\frac{\partial L}{\partial M_k^{uc}} \leq 0 \perp M_k^{uc} \geq 0 \Leftrightarrow p_k^d - p_{w,k} - \gamma_k - c_{w,k} - t_k^{uc} \leq 0 \perp M_k^{uc} \geq 0, \forall k \in K \tag{32}$$

$$\frac{\partial L}{\partial M_k^{oc}} \leq 0 \perp M_k^{oc} \geq 0 \Leftrightarrow p_k^d - p_{w,k} - c_{w,k} - t_k^{oc} \leq 0 \perp M_k^{oc} \geq 0, \forall k \in K \tag{33}$$

According to condition (23), the implementation of the minimum price policy implies that a portion of raw milk production $\left(Q^m\right)$ is intended for milk collection centers $\left(Tr\right)$, and the excess production of milk $\left(v\right)$ is intended for home-made dairy products. Condition (30) shows that: *i*) when the minimum price policy is not effective, we have $v = 0$ (no excess production of raw milk) and $p^m < p_{\min}$; *ii*) when the minimum price policy is effective, we have $v > 0$ (excess production of the raw milk) and $p^m = p_{\min}$.[5]

[5]The excess production of raw milk is absorbed by the informal sector for home-made dairy products. For the reference year 2010, this excess is evaluated at 28.23% of global production (see the *Groupementinterprofessionnel* de *viande rouge et du lait* at http://www.annuairepro-tunisie.com/groupement-interprofessionnel-des-viandes-rouges-et-du-lait-givlait-tunis-tunisie.html, accessed June 3, 2016).

One could note that a spatial version of the partial equilibrium model under PF approach can be easily derived. The spatial version of the model is useful in modelling exercice of some economies e.g. Canada, European Union. In appendix A we present the spatial version of the PF partial equilibrium model that include tariffs, minimum access and subsidies to collectors.

2.3 *Comparing the primal approach to the dual approach*

Figures 1.a and 1.b provide, respectively, a simplified illustration of the objective function according to the QF and PF approaches.

<<< Figure 1>>>

Let us assume that consumers' demand and the raw milk supply are represented, respectively, by the segments D and S^m. To simplify the graphic illustration, we suppose that an input unit generates an output unit. The dairy product supply noted by S^f is a parallel shift to the left of S^m because we assume that the processing function is characterised by constant returns to scale. The objective function to maximise according to the QF approach is represented by a grey area in figure 1.a (a+b+c+d+e+f+g). In figure 1.b, we note the grey area by Φ. Thus, the maximisation of the objective function according to the QF approach is equivalent to the minimisation of $(-\Phi)$. The analytical expression of $(-\Phi)$ in figure 1.b is the function Θ defined by the equation (21).

Analytically, the PF approach, without the minimum price policy, is based on a system composed of 10 inequations and 10 endogenous variables. If we add to the system the equations of farm milk supply and the demand of dairy product k defined respectively by (19) and (20), the model is then composed of 12 inequations and 12 endogenous variables. Equations (19) and (20) are respectively equivalent to equations (13) and (8) in the inequation system according to the QF approach. Ultimately, both inequation systems to solve are identical according to the two approaches. Indeed, the derivatives of the Lagrange function with respect to the endogenous variables according to the PF approach are also the derivatives of the Lagrange function with respect to multipliers according to the QF approach and vice-versa. Moreover, there is complementarity between quantity (price) equations and price (quantity) variables.

3 An analysis of the removal of a minimum price policy in the Tunisian dairy sector

The objective of this section is to evaluate the market impacts of removal of a minimum price policy in the Tunisian dairy sector using a partial equilibrium model according to the price formulation approach.

3.1 Data and Calibration

Several hypotheses are required to calibrate the parameters of the model. We have calibrated the raw milk production cost by using the data of the reference year 2010. The farm supply elasticity was set to 1.68 as in Fezzani and Thabet (1995). The data related to the price, production and collected quantities of raw milk come from the Interprofessional Grouping for Red Meats and Milk (*Groupement interprofessionnel* de *viande rouge et du lait*).[6] The dairy component data were obtained from the Food Quality Computer Centre (CIQUAL), the Délice Trademark in Tunisia and the Canadian Dairy Commission[7]. Under the assumption of constant returns to scale, the cost function associated with

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[6] See at http://www.annuairepro-tunisie.com/groupement-interprofessionnel-des-viandes-rouges-et-du-lait-givlait-tunis-tunisie.html. Accessed June 3, 2016.

[7] See at http://www.dairyinfo.gc.ca/index_e.php. Accessed June 3, 2016.

production of good k : $C_k\left(Q_k^o\right)=G_k Q_k^o$; where G_k is marginal cost. It cannot be calibrated by using the first-order condition $\sum_{s\in S} b_{s,k}pc_s + G_k - p_k^o = 0$ because of a lack of data on component prices in Tunisia. To avoid this problem, we use the data on the technical relationship between raw milk and dairy products $\left(\xi_k\right)$ reported in Meyer and Duteurtre (1998). The conversion factors differ according to their calculation methods based on milk and dairy product composition (milk equivalent) or on the efficiency of the process (yield). In our analysis, milk equivalents are used as a measure because all possible milk by-products are considered simultaneously. They can be added together, as opposed to the measure based on the efficiency of the process. Thus, we obtain an approximation of processing marginal cost: $G_k = p_k^o - \xi_k . p^m$. The wholesale prices were obtained from the Tunisian distribution channel MAGRO.

Buyers' demand schedules were calibrated using 2010 consumption data and demand elasticities. The consumption data are collected from a consumption survey of the National Institute of Statistics (INS)[8]. The demand elasticities are those reported by Dhehibi and Laajimi (2009) for fluid milk (-0.53), yogurt (-0.39) and butter (-0.54).The demand elasticity of cheese (-0.045) is that reported in Dhehibi and Khaldi (2008). The demand elasticity values of other dairy productsare fixed at (-0.53) according to a USDA study on the price and income elasticities of demand.[9]

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[8]See at http://www.ins.tn/. Accessed April 9, 2016.

[9]See at http://www.ers.usda.gov/data-products/commodity-and-food-elasticities/demand-elasticities-from-literature.aspx#Ped2d81ee78c74245b27781793b0672c6_6_214. Accessed April 9, 2016.

The world prices of different products are obtained from the Canadian Dairy Commission (CDC) and the Italian Statistics Institute (ISTA).[10] The world price of fermented milk is supposed to be equal to the local price in Tunisia because of a lack of data on this product. The exchange rate between the US Dollar and the Tunisian Dinar for the year 2010 is set at the mean of the year 1.433.[11]*Ad-valorem* tariffs, in-quota and over-quotatariffs and MAC were obtained from Tunisian customs. Tables 1 and 2 present the tariffs on different dairy products.

<<< Table 1 and Table 2>>>

The calibration exercise allows us to replicate the data of the reference year 2010. Table3 presents the gap between the prices observed and those predicted by the model. Prices of processed products are very close to the observed values. However, the highest margin of error is 2.89% for yogurt price.

<<< Table 3>>>

In table 4, we present the gap between the observed and predicted values of raw milk quantities.The produced quantities of raw milk generated by the model are 1059 TT. This quantity corresponds to the quantity observed in the reference year 2010. The minimum price policy is effective at a raw milk price of 0.580 D/kg. This policy generates an excess of milk production evaluated at 299 TT in 2010. This value is very close to the value replicated by the model, which is equal to 291 TT. This excess production of milk is intended mainly for various home-made dairy products. The quantity required by the milk collection centres for processing purposes is 760 TT. The model generates 768.5TT of collected milk, which represents a gap of 1% between the observed and collected quantities.

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[10]See at http://en.istat.it/. Accessed April 3, 2016.

[11]See at http://www.bct.gov.tn/bct/siteprod/cours.jsp. Accessed April 3, 2016.

<<< Table 4 >>>

3.2 Simulation and results

We analyse a scenario dealing with the policy of support for raw milk producers called scenario 1. In this scenario, we evaluate the impact of the removal of the raw milk minimum price policy on farm milk and dairy product markets, along with the welfare impacts.

Dairy producers' marginal cost function (i.e. supply function) is critical when measuring welfare implications. A sensitivity analysis regarding farm supply elasticity is proposed in scenario 2. This scenario assumes a supply elasticity of 1. This value has been adopted by Bouamra-Mechemache et al. (2002a, 2002b) and Abbassi et al. (2008). Table 5 shows the results on the raw milk market. Table 6 presents the impact of the removal of the minimum price policy on prices, produced and consumed quantities of dairy products and welfare.

The removal of the minimum price policy would have a direct impact on lowering prices and production of raw milk, respectively 14.8% and 25%. All the production of raw milk is sold to processors. The excess supply of milk, intended for the informal sector for home-made production, would be null. This price fall would lead to a decrease in the processors' cost, which would be reflected by a drop in prices and an increase in production on the dairy product market.For example, the production of fluid milk, butter and cheese would increase by 4.8%, 0.8% and 0.2% respectively. This growth in production would also be explained by a 3.6% increase in the quantity of collected milk. Taking advantage of the decrease in the price of processed products, consumers would increase their consumption of all dairy products. The required quantities of fluid milk, butter and cheese would grow by 4.8%, 0.5% and 0.2% respectively.

The welfare analysis shows that producers would see their situation worsen due to the decrease in farm milk production and price. Their surplus would dwindle to 43.8%, namely a decrease of 78.6 million Dinars. Further, the price drop and the increase in consumed quantities for all dairy products would lead to an increase in the consumers' surplus of 1.6% that is a rise of 67.8 million Dinars. The processors' surplus is null due to the hypothesis of constant returns of scale at the processing level. Butter and cheese are protected by tariff-rate quotas. The increase in the supply of these two products would reduce import applications, which would lead to a 19.5% reduction in import licence holders' income. The loss of producers and import licence holders would outweigh the consumers' benefit. The global impact on the aggregate welfare would be a reduction of 0.3%, which translates into a loss of 13.3 million Dinars.

The performed sensitivity analysis shows that there are a similarity between the baseline estimates of buyers' surplus and permit holders' rent. However, the baseline estimate of producers' surplus is larger when the slope of marginal cost is steeper.The market impacts of removal of a minimum price policy would be quantitatively more important when the slope of marginal cost is steeper. Otherwise, the qualitative differences between the two scenarios are pretty small. Indeed, on the raw milk market, milk price would go down by 23.6% and collected milk would go up by 5.3%. This would lead, in the dairy product market, to a greater drop in prices than under scenario 1. The prices of fluid milk, butter and cheese would decrease by 14.7%, 1.5% and 6.6% respectively. Thus, the increase in the consumed quantities of all dairy products would be greater under scenario 2. Regarding welfare, consumers' surplus would increase under scenario 2 by 2.6%, corresponding to a gain of 110.1 million Dinars. Producers would see their surplus decrease by 127.8 million Dinars. Import licence holders' income would be 30.7% lower, i.e. a 1.3 million Dinars less. The global effect on the aggregate welfare would be a decline of 0.4%, corresponding to a loss of 18.2 million Dinars.

<<< Table 4 and Table 6>>>

4 Concluding remarks

In this article, we have presented a dairy sector model under the assumption of perfect competition, according to two approaches: “quantity formulation” and “price formulation”. In addition, we have proved the equivalence between both approaches.This results is important because the PF approach is simpler and more suitable for the implementation of price policies on the input or the output market. The numerical illustrations of the PF approach for the Tunisian dairy sector prove that the removal of the minimum price policy would have, as a direct impact, a decrease in the prices of farm milk production. Consequently, the production cost of processors decrease as is dairy products’ prices. Welfare analysis shows that consumers’ surplus would increase, but import licence holders’ income and raw milk producers’ surplus would both decrease. The change in processors’ surplus is null due to the hypothesis of constant returns of scale at the processing level. The loss of the producers’ and import licence holders’ surplus would outweigh the consumers’ benefit. The global impact on the aggregate welfare would be negative. Our sensitivity analysis shows that the qualitative differences between the two scenarios are small.

Based on the numerical results obtained in the study, we recommend that public authorities maintain the minimum price policy because it averts the deterioration of raw milk producers’ surplus. Nevertheless, this policy is effective because it generates an excess in raw milk production estimated at 28.23% in the year 2010, which is intended for various home-made dairy products. Under an effective minimum price policy, the excess in raw milk can be fully absorbed by the formal processing sector only if the public authorities allocate grants to encourage investment in new milk collection centres and in milk drying equipment, especially in disadvantaged rural regions. The latter economic policy coupled with a minimum price policy can not only guarantee a higher income for raw milk producers but it can also be a development factor for underprivileged rural areas. Finally, it is important to note that the DCFTA with EU threatens the ability to control prices on the local market and the possibility of supporting of raw milk producers through the minimum price policy. To maintain producers' support, the Tunisian government should consider all dairy products as sensitive (as do Canada, USA, the European Union, etc.) and support a trade liberalisation scenario with moderate tariff cuts and a small increase in the MAC over a long period.

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Appendix

Spatial version of the model according to the price formulation approach

Let us take a model linking N regions with the rest of the world as developed by Bouamara et al. (2002) and Abbassi et al. (2008). We suppose that there is no interregional trade in raw milk. We note by $t_{i,j,k}$ the transfer of dairy product k from region i to region j with unit transportation costs of k represented by $c_{i,j,k}$. The imports of product k for region i for under a MAC are noted by $M_{i,k}^{uc}$ with in-quota tariff t_k^{uc}. We denote as $\overline{M}_{i,k}$ the minimum access level authorized for every product k. The dairy product imports of region i over MAC, $M_{i,k}^{oc}$, are submitted to over-quota tariffs, denoted by t_k^{oc}.The optimisation problem of the spatial version according to the PF approach is presented as follows:

$$
\begin{cases}
\underset{\left\{p_i^m, p_{i,k}^d, p_{i,k}^o, pc_{s,i}, \gamma_{i,k}\right\}}{Min} \quad \Theta = \sum_{i \in N} \left[\int_0^{p_i^m} Q_i^m(p)dp - \sum_k \int_0^{p_{i,k}^d} Q_{i,k}^d\left(\overline{p}\right)d\overline{p} + \gamma_{i,k}\overline{M}_{i,k} \right] \\
p_{i,k}^o + c_{i,j,k} \geq p_{j,k}^d, \forall k \in K, \forall i \in N \\
p_{w,k} + c_{w,i,k} + t_k^{uc} + c_{i,j,k} + \gamma_{i,k} \geq p_{i,k}^d, \forall k \in K, \forall i \in N \\
p_{w,k} + c_{w,i,k} + t_k^{oc} \geq p_{i,k}^d, \forall k \in K, \forall i \in N \\
\sum_{s \in S}\left[b_{s,k} pc_{s,i}\right] + G_{i,k} \geq p_{i,k}^o, \forall k \in K, \forall i \in N \\
p_i^m + c_i^m \geq \sum_{s \in S} a_s pc_{s,i}, \forall i \in N
\end{cases}
$$

The Lagrangean expression associated to this problem is written as:

$$
\begin{aligned}
L = & \sum_i \left[\int_0^{p_i^m} Q_i^m(p)dp - \sum_k \int_0^{p_{i,k}^d} Q_{i,k}^d\left(\overline{p}\right)d\overline{p} + \gamma_{i,k}\overline{M}_{i,k} \right] + \sum_{i,j}\sum_k t_{i,j,k}\left(p_{j,k}^d - c_{i,j,k} - p_{i,k}^o\right) \\
& + \sum_i \sum_k M_{i,k}^{uc}\left(p_{i,k}^d - p_{w,k} - c_{w,i,k} - t_k^{uc} - \gamma_{i,k}\right) + \sum_i \sum_k M_{i,k}^{oc}\left(p_{i,k}^d - p_{w,k} - c_{w,i,k} - t_k^{oc}\right) \\
& + \sum_i \sum_k Q_{i,k}^o\left(p_{i,k}^o - \sum_{s \in S}\left[b_{s,k} pc_{s,i}\right] - G_{i,k}\right) + \sum_i Tr_i\left(\sum_{s \in S} a_s pc_{s,i} - p_i^m - c_i^m\right)
\end{aligned}
$$

The Kuhn-Tucker conditions can be represented as mixed complementary conditions:

$$\frac{\partial L}{\partial p_i^m} \geq 0 \perp p_i^m \geq 0 \Leftrightarrow \left(-\frac{a_i}{b_i}+\frac{1}{b_i}p_i^m\right)-Tr_i \geq 0 \perp p_i^m \geq 0, \forall i \in N$$

$$\frac{\partial L}{\partial p_{i,k}^d} \geq 0 \perp p_{i,k}^d \geq 0 \Leftrightarrow -\left(\frac{a_{ik}^d}{b_{ik}^d}-\frac{1}{b_{ik}^d}p_{i,k}^d\right)+t_{i,j,k}+M_{i,k}^{uc}+M_{i,k}^{oc} \geq 0 \perp p_{i,k}^d \geq 0, \forall k \in K, \forall i \in N$$

$$\frac{\partial L}{\partial p_{i,k}^o} \geq 0 \perp p_{i,k}^o \geq 0 \Leftrightarrow -T_{i,k}+Q_{i,k}^o \geq 0 \perp p_{i,k}^o \geq 0, \forall k \in K, \forall i \in N$$

$$\frac{\partial L}{\partial pc_{s,i}} \geq 0 \perp pc_{s,i} \geq 0 \Leftrightarrow -\sum_{k \in K} b_{s,k}Q_{i,k}^o + a_s Tr_i \geq 0 \perp pc_{s,i} \geq 0, \forall s \in S, \forall i \in N$$

$$\frac{\partial L}{\partial \gamma_{i,k}} \geq 0 \perp \gamma_{i,k} \geq 0 \Leftrightarrow -M_{i,k}^{uc}+\overline{M}_{i,k} \geq 0 \perp \gamma_{i,k} \geq 0, \forall k \in K, \forall i \in N$$

$$\frac{\partial L}{\partial t_{i,j,k}} \leq 0 \perp t_{i,j,k} \geq 0 \Leftrightarrow -p_{i,k}^o - c_{i,j,k} + p_{j,k}^d \leq 0 \perp t_{i,j,k} \geq 0, \forall k \in K, \forall i \in N, \forall j \in N$$

$$\frac{\partial L}{\partial Q_{i,k}^o} \leq 0 \perp Q_{i,k}^o \geq 0, -\sum_{s \in S} b_{s,k} pc_{s,i} - G_{i,k} + p_{i,k}^o \leq 0 \perp Q_{i,k}^o \geq 0, \forall k \in K, \forall i \in N$$

$$\frac{\partial L}{\partial Tr_i} \leq 0 \perp Tr_i \geq 0 \Leftrightarrow -p_i^m - c_i^m + \sum_{s \in S} a_s pc_{s,i} \leq 0 \perp Tr_i \geq 0, \forall i \in N$$

$$\frac{\partial L}{\partial M_{i,k}^{uc}} \leq 0 \perp M_{i,k}^{uc} \geq 0 \Leftrightarrow -p_{w,k} - c_{w,i,k} - \gamma_{i,k} - t_k^{uc} + p_{i,k}^d \leq 0 \perp M_{i,k}^{uc} \geq 0, \forall k \in K, \forall i \in N$$

$$\frac{\partial L}{\partial M_{i,k}^{oc}} \leq 0 \perp M_{i,k}^{oc} \geq 0 \Leftrightarrow -p_{w,k} - c_{w,i,k} - t_k^{oc} + p_{i,k}^d \leq 0 \perp M_{i,k}^{oc} \geq 0, \forall k \in K, \forall i \in N$$

List of tables

Table 1. Dairy products submitted to ad-valorem tariffs

Products	Ad-valorem tariffs
Fresh milk	36%
Concentrated milk	30%
Fermented milk	10%
Yogurt	36%
Ice cream	36%

Source: Tunisian Customs (2010).

Table 2. In-quota and over-quota tariffs and minimum access commitments of Tunisian dairy TRQs

Product description	Average tariffs		MAC (tons)
	Under-quota	Over-quota	
Butter	35	100	4000
Cheese	27	139	1500

Source: Documents from OMC G/AG/N/TUN/29, 7 June, 2004, G/AG/N/TUN/31, 22 February, 2005and G/AG/N/TUN/34, 11 July, 2005.

Table 3. The gap between the prices observed and those predicted by the model

Product	Observed prices	Predicted prices	Gap
Fluid milk	0.944	0.934	1.06%
Yogurt	2.114	2.053	2.89%
Butter	6.760	6.741	0.28%
Cheese	8.500	8.440	0.71%
Ice cream	4.200	4.169	0.74%
Concentrated milk	4.629	4.609	0.43%
Fermented milk	1.335	1.304	2.32%

Unit price in Dinars per kilogram (D/kg).

Table 4. The gap between the observed and predicted values of raw milk quantities.

	Farm milk
Observed Produced Quantity	1 059.0
Predicted Produced Quantity	1059
Gap	0.0%
Observed Collected Quantity	760.0
Predicted Collected Quantity	768.5
Gap	1.0%
Observed Milk Surplus	299.0
Predicted Milk Surplus	291.0
Gap in %	-2.7%

Unit: Thousand Tons (TT).

Table 5. Minimum price policy impact on the farm milk market

	Basic scenario	Scenario 1 (change %)	Scenario 2 (change %)
Price (in D/Kg)	0.580	-14.8	-23.6
Production (in thousand tons)	1 059.0	-25.0	-23.6
Collected milk (in thousand tons)	768.5	3.6	5.3

Table 6. Minimum price policy impact on the market of dairy products and on welfare

Panel a. Impact on the market	Fluid milk	Butter	Cheese	Fermented milk	Yogurt
Consumption (in thousand tons)	459.2	10.6	35.9	57.7	54.4
Scenario 1 (% change)	4.8	0.5	0.2	2.9	1.8
Scenario 2 (% change)	7.6	0.8	0.3	4.7	3.1
Production (in thousand tons)	459.2	6.5	34.4	57.7	54.4
Scenario 1 ((% change)	4.8	0.8	0.2	2.9	1.8
Scenario 2 (% change)	7.6	1.3	0.3	4.7	3.1
Wholesale price (in D/kg)	0.93	6.76	8.44	1.30	2.05
Scenario 1 (% change)	-8.6	-1.2	-4.1	-5.4	-4.9
Scenario 2 (% change)	-14.7	-1.5	-6.6	-8.7	-8.1

Panel b. Impact on the welfare	Buyers' surplus	Producers' surplus	Import licence income	Total welfare
Surplus				
Scenario 1 (supply elasticity equal to 1.68)				
Baseline surplus (million Dinars)	4 236.7	182.8	4.1	4 423.6
% change of the surplus	1.6	-43.8	-19.5	-0.3
Scenario 1 (supply elasticity equal to 1				
Baseline surplus (million Dinars)	4 236.7	307.1	4.1	4 547.9
% change of the surplus	2.6	-41.6	-30.7	-0.4

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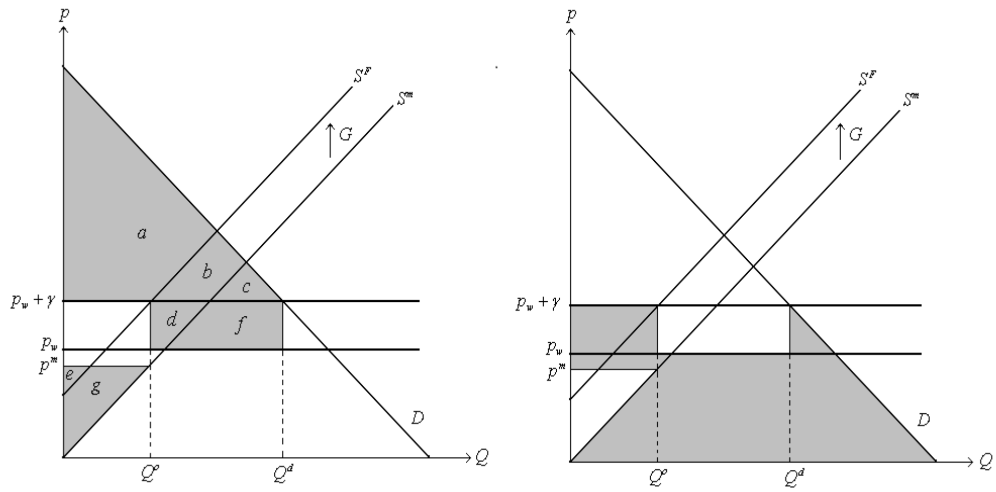

Figure1.a. The objective function according to the QF approach

Figure 1.b. The objective function according to the PF approach.

Figure 1. Objectives function of the quantity formulation and the price formulation