

Endogenous Adjustment of Quotas: The Case of Swiss Raw Milk Production*

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Abstract

This paper discusses an approach to implementing output quotas in the GTAP model which permits an endogenous change from a binding to a non-binding status and vice versa. The quota rent is interpreted as additional earnings of the factors used. The suggested approach requires no change of the data base. In return, several modifications of the GTAP standard model are required: a quota condition is introduced and the zero profit condition is replaced. Furthermore, the equation of the regional income is expanded by changing the quota rent and employing a necessary correction term.

To illustrate this approach the potential impact of a total elimination of Swiss export subsidies is analyzed. A result of this would be that Swiss raw milk production would no longer attain its quota quantity and the loss of the quota rent would reduce the Swiss raw milk price remarkably.

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1 Introduction

Since the late 1970s Switzerland has had a quota for its raw milk production sector. Due to the fact that raw milk production is the most important sector of Swiss agriculture the quota has had a remarkable influence on agricultural policy for the last twenty years.

It is therefore necessary to implement the quota system in order to be able to correctly analyze the impacts of the ongoing negotiation round of the World Trade Organization (WTO) with the general equilibrium model of the Global Trade Analysis Project (GTAP, Hertel) on Switzerland.

A currently used approach is to supplement the data base with the quota rent. One possible way to do so is to divide the sector tax into a tax and a quota rent. During simulation quantity is exogenously fixed and the quota rent can adjust endogenously (Nielsen, p.2; Bach et al., p.167; van Meijl and van Tongeren, p.13).

There are three reasons why this approach is not appropriate for the Swiss raw milk production. For one, it seems possible that the supplied quantity falls below quota quantity. This might happen if agricultural protectionism was reduced considerably, for example through the elimination of export subsidies. The model should then have the possibility to change endogenously from binding to non binding status. Secondly, in Swiss raw milk production the quota rent is part of the value of output at agent's price. To see the quota rent as a kind of sector tax does not seem realistic. Thirdly, the output of Swiss raw milk production is strongly subsidized. Introducing an additional quota rent also requires enlarging the subsidy to maintain the value of output at market price level. Otherwise a modification of the whole data base is necessary.

In this paper another approach is elaborated. The basic idea is to interpret the quota rent as an additional factor payment. Regarding the Swiss raw milk quota this approach has three advantages: Firstly, it facilitates an endogenous adjustment of quotas. Secondly, no change of the data base is required and finally, the quota rent is included at agent level.

The remaining sections of this paper are organized as follows: Section two includes a few remarks about quotas and their application in linearized general equilibrium models as well as in the proposed approach. In the third section the necessary adjustments to the GTAP standard model are discussed. An example in section four illustrates the proposed representation of quotas and leads to some conclusions in section five.

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2 Quotas and their modeling

The situation of the Swiss raw milk production as it is today is shown in figure 1a. Without quota the market equilibrium would be at point T and the supplied quantity would be $QO_{i,r}$. Due to the quota ($QO_Quota_{i,r}$) the supply function is $S'_{i,r}$ instead of $S_{i,r}$. Accordingly, the market equilibrium is at the price $PS_{i,r}$ (point R). Since the production costs are only equal to the price $PQ_{i,r}$, a quota rent ($Rent_L_{i,r}$) exists, which belongs to the producers.

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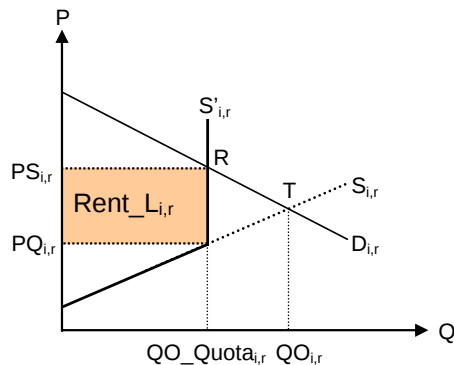
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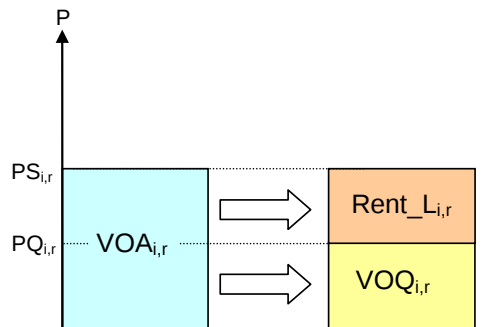
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Figure 1: Raw milk quota in Switzerland

a) Output quota



b) Decomposition of $VOA_{i,r}$



Following Bach and Pearson, the status of a quota of sector i in region r can be defined with two ratios:

$$QQO_L_{i,r} = \frac{QO_{i,r}}{QO_Quota_{i,r}} \quad \text{and}$$

$$TQ_L_{i,r} = \frac{PQ_{i,r}}{PS_{i,r}} \quad \text{equation 1}$$

If a quota is binding, then $QQO_L_{i,r} = 1$ and $TQ_L_{i,r} \leq 1$. If it is not binding, then $QQO_L_{i,r} < 1$ and $TQ_L_{i,r} = 1$. This leads to a condition which must be fulfilled in every case (Bach and Pearson, p.16):

$$\max(QQO_L_{i,r}, TQ_L_{i,r}) = 1$$

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Bach and Pearson also provide a method to implement this condition in models solved through the use of the Gempack software (Harrison and Pearson).

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In the case of Swiss raw milk production the quota rent is interpreted as an additional factor payment. At price $PQ_{i,r}$, resp. the production costs, a minimal necessary factor payment is

included. Due to the quota the supply side receives an additional payment for the factors used.

Together, these ~~extra~~ payments ~~for~~ all factors used in sector i in region r yield the quota rent of sector i in region r.

Figure 1a shows that the producers are willing to supply the quota quantity at the price $PQ_{i,r}$ and consequently to renounce the quota rent. If output price rises over $PQ_{i,r}$ we can safely assume that no change ~~in the~~ production process will occur. In other words, Swiss milk farmers would use the same amount ~~of~~ factor inputs regardless of whether they received a quota rent or not.

In the GTAP model price $PS_{i,r}$ shows the output price at agent level and refers to the output value $VOA_{i,r}$ ². Introducing quotas requires ~~us~~ to split $VOA_{i,r}$ into a quota rent and the effective production costs which are denoted as $VOQ_{i,r}$ ³ (figure 1b). $VOQ_{i,r}$ includes only the minimal necessary factor payment. In the GTAP standard model the zero profit condition must hold at value $VOA_{i,r}$. Since $VOA_{i,r}$ includes the quota rent, this no longer makes sense. The zero profit condition must be switched to value $VOQ_{i,r}$.

There are two ~~conceivable ways to introduce~~ the proposed approach: ~~For one, it is possible to~~ ~~modify~~ the data base ~~by~~ replacing the factor costs ~~with~~ the minimal necessary factor payment and the quota rent. ~~However,~~ introducing new values into the GTAP data base would require remarkable effort. Furthermore, ~~it would necessitate altering~~ the model.

The second ~~method requires no~~ change of the data base. The quotas ~~can be represented by~~ the two coefficients $QO_{i,r}$ and $TQ_{i,r}$. In return, a substantial change of the GTAP standard model ~~is called for~~. ~~Also, the following five~~ aspects must be considered: Firstly, the quota must be implemented as suggested by Bach and Pearson. Secondly, an adjustment of the zero profit condition by modifying the cost shares of all inputs is required. Thirdly, factor ~~markets~~ will remain unaffected since the quota rent has ~~no~~ influence on factor use. The changes ~~in~~ factor use are equal ~~to what~~ they would be without ~~a~~ quota. Fourthly, the quota rent ~~is related to~~ the regional income. Any change of the rent must be considered. Finally, since the data base does not change we need a correction term in the equation of the regional income.

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² $VOA_{i,r}$ is the Value of Output i at Agents price in region r; $VOA_{i,r} = QO_{i,r} * PS_{i,r}$

³ $VOQ_{i,r} = QO_{i,r} * PQ_{i,r}$

3 Necessary modification of the GTAP standard model

Since the data base remains unchanged, the values $VOQ_{i,r}$ and $Rent_{L_{i,r}}$ have to be defined in the model. This can be done with the coefficient $TQ_{L_{i,r}}$. If we multiply both numerator and denominator of equation 1 with $QO_{i,r}$ we get:

$$TQ_{L_{i,r}} = \frac{VOQ_{i,r}}{VOA_{i,r}} \quad \text{equation 2}$$

Using equation 2 we can calculate $VOQ_{i,r}$ and $Rent_{L_{i,r}}$ for sector i in region r:

$$\begin{aligned} VOQ_{i,r} &= TQ_{L_{i,r}} * VOA_{i,r} \\ Rent_{L_{i,r}} &= VOA_{i,r} - VOQ_{i,r} \end{aligned} \quad \text{equation 3}$$

A graphic presentation of all these values is supplied in the appendix.

We only need the minimal necessary factor payment for the new zero profit condition. The data base still includes the factor costs which are equal to the sum of the minimal necessary factor payment and the additional factor payment. Factor costs are denoted as $VFA_{j,i,r}$ the value of input j into sector i in region r at agent level. The coefficient $VFA_{j,i,r}$ is used for factors as well as for intermediate inputs. We can distinguish them by the set they belong to.

While factors are elements of set $ENDW$, intermediate inputs belong to set $TRAD$. We introduce the coefficient $FactorQ_{i,r}$ representing the ratio of minimal necessary factor payment and factor costs in the data base. $FactorQ_{i,r}$ refers to all factors used in sector i in region r:

$$FactorQ_{i,r} = \frac{\sum_{j \in ENDW} VFA_{j,i,r} - Rent_{L_{i,r}}}{\sum_{j \in ENDW} VFA_{j,i,r}} \quad \text{equation 4}$$

$FactorQ_{i,r}$ enables the modification of cost shares for all inputs. In the GTAP model the coefficient $STC_{j,i,r}$ denotes the cost share of input j into sector i of region r. Since the additional factor payment is no longer considered, cost shares of intermediate inputs rise while cost shares of factors decline. Calculating cost shares we have to distinguish between intermediate inputs and factors. The cost share of intermediate input j into sector i in region r is:

$$STC_{j,i,r} = \frac{VFA_{j,i,r}}{\sum_{j \in TRAD} VFA_{j,i,r} + \sum_{j \in ENDW} FactorQ_{i,r} * VFA_{j,i,r}}$$

For factors the cost share is different:

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$$STC_{j,i,r} = \frac{FactorQ_{i,r} * VFA_{j,i,r}}{\sum_{j \in TRAD} VFA_{j,i,r} + \sum_{j \in ENDW} FactorQ_{i,r} * VFA_{j,i,r}}$$

The output price directly affected by the zero profit condition is no longer $PS_{i,r}$ as in the GTAP standard model, but $PQ_{i,r}$. Since GTAP is a linearized model, equation 1, which depicts the relation of the two prices $PS_{i,r}$ and $PQ_{i,r}$ must be linearized too⁴:

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$$tq_{i,r} = pq_{i,r} - ps_{i,r}$$

Although changing the quota rent has no impact on factor allocation, it affects regional income. Modifying equation 3 yields:

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$$Rent_{L_{i,r}} = QO_{i,r} * (PS_{i,r} - PQ_{i,r}) \quad \text{equation 5}$$

The linearized form of equation 5 is:

$$rent_{i,r} = qo_{i,r} + \frac{ps_{i,r} * PS_{i,r}}{PS_{i,r} - PQ_{i,r}} - \frac{pq_{i,r} * PQ_{i,r}}{PS_{i,r} - PQ_{i,r}} \quad \text{equation 6}$$

The coefficient $TQ_{L_{i,r}}$ facilitates equation 6:

$$rent_{i,r} = qo_{i,r} + ps_{i,r} * \left[\frac{1}{1 - TQ_{L_{i,r}}} \right] - pq_{i,r} * \left[\frac{TQ_{L_{i,r}}}{1 - TQ_{L_{i,r}}} \right] \quad \text{equation 7}$$

If the quota is not binding, $TQ_{L_{i,r}}$ is equal to 1. In this case a fall differentiation is needed to prevent the denominator being equal to zero. Before adding equation 7 to the regional income we have to summarize overall sectors i in region r, which are included in the set TRAD:

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$$+ \sum_{i \in TRAD} Rent_{L_{i,r}} * rent_{i,r} \quad \text{equation 8}$$

Equation 8 has to be added to the regional income.

The use of the GTAP standard data base provokes an unwanted effect which has to be neutralized with a correction term. The factor costs of the data base include both the minimal

⁴ Following the notation of the GTAP model lower case letters refer to percentage changes. For instance $pq_{i,r}$ is the percentage change of $PQ_{i,r}$. $tq_{i,r}$ is percentage change of $TQ_{L_{i,r}}$.

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necessary factor payment and the additional factor payment. During the simulation, the model refers changes in factor quantities ($qfe_{j,i,r}$) and prices ($pfe_{j,i,r}$) to the whole value of factor cost in the data base ($VFA_{j,i,r}$). However, this is not the correct procedure since only changes in minimal necessary factor payment should be taken into account. The correction term for factor j into sector i in region r is:

$$-[(1 - FactorQ_{i,r}) * VFA_{j,i,r}] * (qfe_{j,i,r} + Pfe_{j,i,r}) \quad \text{equation 9}$$

Again we have to summarize all factors j of all sectors i in region r:

$$- \sum_{i \in \text{TRAD}} \sum_{j \in \text{ENDW}} [(1 - FactorQ_{i,r}) * VFA_{j,i,r}] * (qfe_{j,i,r} + Pfe_{j,i,r}) \quad \text{equation 10}$$

Enlarging the regional income equation with equations 8 and 10 ensures a correct depiction of regional income. Accordingly, the model attains a general equilibrium. Since the equation of regional income is changed this also implies the modification of the welfare decomposition provided by Huff and Hertel. It results in an additional welfare effect. Yet since the welfare decomposition does not affect our model solution we will neglect this derivation.

Implementing the proposed approach permits the introduction of an output quota for each produced commodity in every region. Though normally only a few sectors have a quota, both coefficients $QQO_{L_{i,r}}$ and $TQ_{L_{i,r}}$ are required for all sectors. For sectors without quota $TQ_{L_{i,r}}$ is equal to 1 and $QQO_{L_{i,r}}$ has a small value like 0.1.

If a sector has a quota and, moreover, attains quota quantity, $QQO_{L_{i,r}}$ is equal to 1. Defining the value of $TQ_{L_{i,r}}$ is challenging because the price $PQ_{i,r}$ is hard to follow, especially at agent level. Prices at market level seem to be more appropriate for estimating the minimal price at which quota quantity is supplied. Therefore we denote $PQ_{i,r}$ as $PS_{i,r}^{min}$. Equation 1 becomes:

$$TQ_{L_{i,r}} = \frac{PS_{i,r}^{min}}{PS_{i,r}} \quad \text{equation 11}$$

Both numerator and denominator are divided by $TO_{i,r}$, the rate of the output tax of sector i in region r. Using the level form of GTAP equation 15 yields⁵:

⁵ The level form of GTAP equation 15 (OUTPUTPRICES) is: $PM_{i,r} = \frac{PS_{i,r}}{TO_{i,r}}$ $PM_{i,r}$ is the price of output i in region r at market level.

$$TQ_{L_{i,r}} = \frac{PM_{i,r}^{min}}{PM_{i,r}}$$

equation 12

$PM_{i,r}^{min}$ is the lowest possible price at which the quota quantity is supplied, measured at market level. It is possible to derive $TQ_{L_{i,r}}$ from prices at agent level (equation 1 or 11) as well as from prices at market level (equation 12).

4 The case of elimination of Swiss export subsidies

To illustrate how the implementation of quotas works we will simulate the unilateral elimination of all Swiss export subsidies. Switzerland subsidizes its exports of dairy products (primarily cheese) and, much more modestly, products of other food industries.

The simulation is done twice: The GTAP standard model and the modified GTAP model, as described in the previous section, are used. A three region (Switzerland, European Union and Rest of the world) and eighteen sector aggregation is used. The sectors are wheat, other grains, vegetables and fruits, oilseeds, sugar beet, other crops, cattle, pork and poultry, raw milk production, red meat, white meat, vegetable oils, dairy products, sugar, other food industries, beverages and tobacco, industry and, finally, services.

We use the second draft of the release 5 of the GTAP data base which refers to the year 1997 (McDougall et al.) as this was the first release of the GTAP data base which included Switzerland as a single region. To eliminate a few inaccurate values, the data base is adjusted as suggested by Malcolm.

Beside a quota for raw milk production Switzerland has a quota for the production of sugar beet. For both Swiss sectors we need the two coefficients $QQO_{L_{i,r}}$ and $TQ_{L_{i,r}}$. Since both sectors attain their quota quantities $QQO_{L_{sugar\ beet, Switzerland}}$ and $QQO_{L_{raw\ milk, Switzerland}}$ are equal to 1. The estimated value for $TQ_{L_{sugar\ beet, Switzerland}}$ is 0.8. For $TQ_{L_{raw\ milk, Switzerland}}$ we will use a study which investigated the behavior of ten representative Swiss farm types with regard to their willingness to produce raw milk under different political condition by using a linear programming model (Lehmann, Eggenschwiler et al.). From this investigation we derive a sector wide price $PM_{raw\ milk, Switzerland}^{min}$ which is SFr. 0.60. The corresponding $PM_{raw\ milk, Switzerland}$ is SFr. 0.81 (Schweizerischer Bauernverband). The resulting value for $TQ_{L_{raw\ milk, Switzerland}}$ is 0.74.

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As suggested by Bach and Pearson, the modified GTAP model is run twice. The first time serves to examine whether the quotas remains binding or not. According to this result, the closure for the second run is chosen. Both times Euler algorithm is used. The most important results for Switzerland are presented in tables 1 and 2. They contain the changes of quantities and prices respectively.

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Table 1: Change of output quantity ($q_{i,r}$) in % of Swiss sectors

	GTAP standard model	GTAP model with quota
wheat	-4.2	-3.8
other grains	-1.8	-1.2
vegetables, fruits	0.1	0.2
oilseeds	0.7	0.1
sugar beet	-2.0	0.0
other crops	-1.4	-0.7
cattle and sheep	-0.7	1.0
pork and poultry	-0.3	0.2
raw milk production	-8.4	-4.0
red meat	0.0	0.9
white meat	0.0	0.3
vegetable oils and fats	-1.2	-0.8
dairy products	-12.0	-6.2
sugar	-2.0	0.1
other food industries	-5.7	-5.0
beverages and tobacco	0.3	0.4
industry	0.4	0.2
services	0.2	0.1

Table 2: Change of prices at agent level ($ps_{i,r}$) in % of Swiss sectors

	GTAP standard model	GTAP model with quota
wheat	-2.2	-1.3
other grains	-2.2	-1.2
vegetables, fruits	-0.6	-0.3
oilseeds	-2.1	-1.1
sugar beet	-1.3	-4.1
other crops	-0.2	-0.1
cattle and sheep	-1.3	-5.6
pork and poultry	-0.7	-0.8
raw milk production	-1.8	-28.0
red meat	-0.6	-3.4
white meat	-0.3	-0.6
vegetable oils and fats	-0.4	-0.3
dairy products	-1.0	-13.9
sugar	-0.7	-2.0
other food industries	-0.3	-0.6
beverages and tobacco	-0.2	-0.2
industry	-0.1	0.0
services	-0.1	-0.1

Due to the elimination of export subsidies the exported quantities of dairy products and other food industries decline noticeable. This leads to decreases in output for both sectors - dairy products and other food industries. We can observe this effect in both models, though it is stronger with dairy products due to originally higher exports subsidies (table 1). The dairy products sector uses a preponderant part of the output of the sector of raw milk production. Both models show a reduction of raw milk production. In the case of the modified GTAP model this means that the quota quantity is no longer reached. In addition, it also means that the quota rent ceases to exist, which in turn leads to a strong price reduction of 28% (table 2). Since raw milk is the most important input for dairy production the output price of dairy products therefore declines remarkably. In the model without quota, however, this price reduction is quiet modest. The discrepancy between the output prices for dairy products explains why the two models differ in the output quantities of both dairy products and raw milk production: In the modified GTAP model the elimination of export subsidy is partly compensated with a smaller output price due to the loss of the quota rent.

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The other Swiss sector with a quota (sugar beet) is only slightly affected by the elimination of export subsidies. In the modified GTAP model quota quantity remains attained, since the change in output quantity is exactly 0% (table 1).

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The basic cause for the different model results is the relatively small value of the coefficient $TQ_{L_{raw\ milk, Switzerland}}$, resp. the respectable quota rent of Swiss raw milk production. If $TQ_{L_{raw\ milk, Switzerland}}$ has a value close to 1 resp. a small quota rent, the difference would be smaller.

5 Conclusions

The results in the previous section show clearly that model outcomes are strongly affected if quotas are implemented. As long as a part of the quota rent exists, the raw milk production sector does not reduce output quantity. Consequently, compared to the GTAP standard model the modified model shows smaller effects if quantities change and stronger effects if prices change. This leads to other effects in both domestic demand and exports. Additionally, if the factor income of the agricultural sector is a subject of interest a model with implemented quotas may provide important insights.

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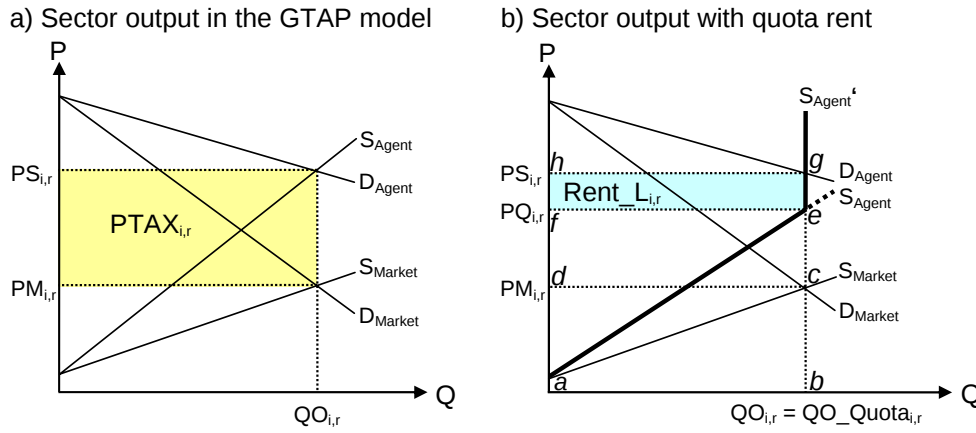
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6 Appendix

To illustrate the introduction of the quota within the values of the GTAP model we use the graphical presentation by Brockmeier. At agent price level there is the supply function S_{Agent} and the demand function D_{Agent} . Accordingly at the market equilibrium we get the quantity $QO_{i,r}$ and the price $PS_{i,r}$, which refers to the value $VOA_{i,r}$ since $VOA_{i,r} = QO_{i,r} * PS_{i,r}$. If we take the sector subsidy $PTAX_{i,r}$ into consideration we get the situation at market price level. The supply function turns from S_{Agent} to S_{Market} and the demand function from D_{Agent} to D_{Market} . The price of the market equilibrium at this price level is $PM_{i,r}$. Again the corresponding quantity must be $QO_{i,r}$ since we are looking at the same market.

Figure 2: Sector output in the GTAP model⁶



In figure 2b an output quota is introduced using exactly the same situation as in figure 2a. Since the quota is binding $QO_{i,r}$ is identical to $QO_Quota_{i,r}$. The supply function at agent level depends on whether the quota quantity is attained or not. As long as quota quantity is not reached S_{Agent} depicts the supply function. Attaining quota quantity the supply function switches into a vertical function denoted as S_{Agent}' . Since demand intersects supply in the vertical area a quota rent ($Rent_L_{i,r}$) results.

Figure 2b includes all important values: $VOQ_{i,r}$ (abef), $Rent_L_{i,r}$ (fegh), $VOA_{i,r}$ (abgh), $PTAX_{i,r}$ (dcgh) and $VOM_{i,r}$ (abcd).

⁶ following figure 5.1 of Brockmeier

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