Trade Balance Constraints and Optimal Regulation*

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Abstract

We investigate the interactions between optimal regulation and external credit constraints. When part of a regulated firm is owned by foreign investors, a credit-constrained country who wants to send profits abroad has to generate enough surplus in the trade account in order to compensate capital outflows. We show that the credit constraint translates into a constraint of maximum profits for the regulated firm. Overall efficiency in the regulated sector is reduced to maintain incentive compatibility. A flexible exchange rate helps relaxing the credit constraint. Efficiency is higher than with a fixed exchange rate, but still lower than without credit constraints.

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1 Introduction

The share of the regulated sector in GDP may be quite large in developing countries. Moreover, the participation of foreign investors in the ownership of regulated firms is far from being negligible.

Can regulation design be considered independently from the external sector performance? Most probably, a regulated firm will want to transfer profits to its foreign owners after investing in the host country. However, capital outflows have to be compensated by inflows, either from the capital account, via borrowing, or from a surplus in the trade account. If the country is credit-constrained, the trade account becomes the only means the country can use to finance capital outflows.

On the other hand, domestic ownership is not enough for solving the problem. In fact, domestic agents could exhibit a preference for holding foreign assets, putting pressure on the trade surplus anyhow.

A well-known result of the theory of incentives in regulation is that optimal regulation under asymmetric information implies leaving rents to efficient firms in order to induce them to actually reveal they are efficient (see Baron and Myerson (1982) or Laffont and Tirole (1993)). In some cases, these rents may be quite significant. If a big proportion of the rents has to be sent to foreign owners, the country may face a serious problem trying to increase its exports of goods and services in order to compensate the capital outflows. In particular, a low level of exports may force the country to give lower powered incentives and reduce the regulated sector's overall efficiency.

In this paper we are interested in the interaction between the optimal regulatory policy and the constraints imposed by the external sector. In particular, we analyze how the optimal regulatory mechanism is modified when the country is credit-constrained. Laffont and Matoussi (1995) present a flexible model that includes the possibility of several contracts both when the agent and the principal are credit-constrained. Lewis and Sappington (2000) consider the case of potential operators of unknown ability that are wealth constrained. In our case, it is the principal who must face an additional constraint in a complementary good necessary to develop the contract. These authors do not take into account the possibility of a constraint for the principal expressed in a good different from the good in which the contract is settled. The basic problem in our model is that the regulated firm's foreign owners want to obtain their rent expressed in international currency, while producing a non-tradable good for which revenues are expressed in domestic currency. In this sense, the principal is obliged to make transactions in a different market in order to provide the firm with enough incentives.

The case of Argentina is a good example of an economy where the share of the regulated sector in GDP is important and international credit constraints are binding; this situation will last for several years, and it will probably influence regulatory policy. Moreover, Argentina established a currency board regime in 1991 that lasted for ten years, but recently announced default of its external debt and highly devaluated its currency. Chisari, Estache, Lambardi, and Romero (2003) build a computable general equilibrium model for the Argentine economy and analyze the effects of the constraints imposed by the external sector. They show that both the capital account and the exchange rate regime are relevant variables to choose the regulatory regime.

To analyze this problem, we develop a very simple and stylized model of a small economy of three goods, a tradable good, a non-tradable good and money. We assume that the production of the non-tradable good is performed by a regulated natural monopoly, with a participation of foreign ownership. The regulated monopoly is privately informed about its marginal cost of production and, therefore, an optimal regulation policy will provide the monopoly with incentives to reveal its private information. We assume that the country is credit-constrained in the sense that it cannot borrow money from foreign investor at the equilibrium international interest rate. The country is a net exporter of the tradable good and the monetary value of exports will determine how binding the credit constraint is.

In our model, it turns out that the credit constraint translates into an additional constraint on maximum profits for the regulated firm. The level of exports is somewhat limited because it depends on the international price of the tradable good and the foreign demand function, both variables beyond the control of the country. The credit constraint implies that the capital outflows, equal to the proportion of profits sent abroad, cannot be higher than the monetary value of exports. It is, therefore, imposing an upper bound on the level of profits the firm can earn. As a consequence, the traditional cost of public funds à la Laffont and Tirole (1993) is augmented by a new cost that reflects how strong the credit rationing is. Moreover, this shadow price decreases with the exchange rate, implying that a devaluation has direct positive effects on the efficiency of the regulated sector. We show that the credit constraint has a negative impact on the overall efficiency of the regulated sector. Indeed, if the credit constraint is binding, the regulator has to reduce the rents given to efficient firms, but, due to the incentive problem, it can only do so by reducing production. That is, the regulator will be willing to accept an efficiency loss in compensation for a reduction of pressure on the trade balance.

One interesting finding is that the reduction of the level of production is concentrated in the inefficient types. The new constraint obliges the principal to sacrifice efficiency; since the same set of incentive compatibility and participation constraints are still operative, to minimize the efficiency loss, transfers are reduced for the most efficient type but not her production, and production is reduced for all other types. Indeed, there is no point in reducing production of the most efficient firm because rents are not affected by it.

We show that the effect of the credit constraint on efficiency is more important the larger the proportion of foreign ownership and the smaller the exchange rate. When the proportion of foreign ownership increases, and the level of exports is fixed, the government is obliged to reduce rents in order to satisfy the credit constraint. Therefore, efficiency is reduced further. Similarly, a higher exchange rate raises the value of exports, increasing the rents the regulator can offer to the firm. Also, local opportunities for reinvesting profits could help reducing or reversing the flow and thus, alleviate the credit constraint.

Of course, in a flexible exchange rate regime, the trade balance pressure could be reduced through devaluation. Indeed, a higher exchange rate increases the monetary value of exports, relaxing the credit constraint. However, devaluation is costly, since it increases both the domestic price of tradable goods and the domestic value of the outside option of the regulated firm. The country, then, faces a trade off when determining the optimal exchange rate, so it may not want to completely relax the credit constraint. Assuming that the country optimally sets the exchange rate, we show that optimal regulation still requires lower efficiency if the cost of relaxing the credit constraint completely is high. We also show that the optimal exchange rate is set such that the marginal cost of devaluation is equal to its marginal benefit.[1]

The paper is organized as follows. In Section 2 we develop the model and present the main assumptions. In Section 3, we assume that the exchange rate is fixed. We obtain the regulatory contract with and without credit constraint and we show that production is further reduced when the credit constraint is binding. In Section 4 we assume that the country can optimally determine de exchange rate in order to relax the credit constraint. We show that, in general, the country will not devaluate to completely eliminate the constraint, but it will choose the exchange rate for which the marginal cost equals the marginal benefit. Finally, we conclude in Section 5.

2 The model

Consider a small economy with a tradable good, good T, a non-tradable (regulated) good, good R and money. The tradable good is produced in a competitive industry, through a constant returns to scale technology. This implies that in any equilibrium, the profits of the tradable sector are equal to 0. Moreover, the assumption of small economy implies that the international price of the tradable good is fixed in the international markets and local production cannot influence the equilibrium price.

The non-tradable good industry is a regulated natural monopoly. The government wants to determine the optimal way of designing the regulatory contract in order to

[1]Marginal costs of devaluation include the deviation of the real exchange rate with respect to the long-run steady state and, in the case of highly indebted country, the marginal fiscal effort needed to collect taxes for buying foreign currency to domestic exporters.

maximize social welfare. The regulated firm has private information about its production technology. The government knows that the cost of the regulated firm is

$$C\left(q_R\right)=\theta q_R+k,$$

where q_R is the quantity produced by the firm, k is a fixed cost and the marginal cost, θ, is such that $\theta \in [\theta_L, \theta_H]$ according to a cumulative distribution function $F\left(\theta\right)$ with density $f\left(\theta\right)$. This is common knowledge. We assume that the distribution function satisfies the monotone hazard rate property: $\frac{F(\theta)}{f(\theta)}$ is increasing in θ.

We assume that the surplus obtained is large enough, so the government wants to produce even if the firm turns out to be very inefficient. So, shutting down production is never an optimal option.

The profit of the regulated firm is

$$\pi_R\left(q_R, t, \theta\right)=t+\left(p_R-\theta\right) q_R\left(p_R, p_T^d\right)-k \tag{1}$$

where p_R is the price of the non-tradable good, p_T^d is the domestic price of the tradable good and t is a transfer from the regulator to the firm (t could be negative, in which case it is a tax paid by the firm to the government). We assume that the marginal revenue, $p_R q_R$ is decreasing in q_R. The domestic price of the tradable good is ep_T, where e is the exchange rate and p_T is the international price.

Domestic and foreign investors own the regulated firm. The proportion of domestic capital is $\alpha \in [0,1]$.

There is a representative consumer with quasilinear, separable preferences, whose utility function is characterized by

$$U\left(q_R, q_T, m\right)=m+u_R\left(q_R\right)+u_T\left(q_T\right), \tag{2}$$

where m is the quantity of money consumed by the individual, q_T is the quantity of tradable good and $u_j(\cdot)$ is increasing and concave for $j = R, T$.

The representative consumer maximizes his utility taking as given the prices of the three goods, with the price of money normalized to 1. Demand functions are then independent and such that:

$$\begin{aligned} u'_R\left(q_R\left(p_R\right)\right) &= p_R, \\ u'_T\left(q_T\left(p_T^d\right)\right) &= p_T^d. \end{aligned}$$

Simple comparative static implies that, for $j = R, T$ and $h = R, T$, $j \neq h$,

$$\begin{aligned} \frac{\partial q_j}{\partial p_j} &= \frac{1}{u''_j\left(q_j\right)} < 0, \\ \frac{\partial q_j}{\partial p_h} &= 0. \end{aligned}$$

The objective of the regulator is to determine the optimal regulatory policy. The regulator determines the quantity to be produced by the regulated firm (or similarly, the price of the regulated good) and the transfer to the firm in order to maximize domestic social welfare (DW). Domestic social welfare is equal to the sum of the consumer surplus and the domestic profits of the regulated firm (remember that firms producing the tradable goods make 0 profits given the assumption of constant returns to scale). We assume that the government has to collect money through distortionary taxes in order to subsidize the firm, so in order to give 1\$ to the firm, consumers have to pay $(1+\lambda)$\$ and λ is a measure of the cost of public funds.

$$\begin{aligned} DW &= V\left(q_R, q_T\right) - p_R q_R - p_T^d q_T - (1+\lambda)\, t + \alpha \pi_R \\ & \quad V\left(q_R, q_T\right) + \lambda p_R q_R - p_T^d q_T - (1+\lambda)\left(\theta q_R + k\right) - (1 - \alpha + \lambda)\, \pi_R, \end{aligned}$$

where V is the gross consumer surplus:

$$V\left(q_R, q_T\right) = \int_0^{q_R(p_R)} u_R'\left(v\right) dv + \int_0^{q_T\left(p_T^d\right)} u_T'\left(z\right) dz.$$

There are two reasons why the government dislikes rents in this context. First, rents are relatively less valuable than consumer surplus because a proportion $(1-\alpha)$ goes to consumers abroad. Second, the government is obliged to distort the economy in order to collect money to give rents. Therefore, it is optimal to fix prices above the marginal cost in order to save in distortionary taxes. This is the traditional presentation, that assumes that all fiscal costs are captured by λ. We will show that this parameter is insufficient, particularly for small open economies that face recurrent crisis in their external sector, because it does not account for the costs introduced by international credit rationing.

3 Fixed exchange rate

In a context of complete (symmetric) information, the optimal regulatory contract would give a rent just enough to make the firm willing to participate whatever his type, because, as argued before, rents are costly. Capital outflows would be minimal and, therefore, the credit constraint would have no effect on the optimal regulatory contract. Thus, the credit constraint becomes relevant only if there is asymmetric information, in which case the government finds it optimal to give positive rents in order to make the firm reveal his type.

Assume first that the country has a tight monetary policy in which the exchange rate is fixed and normalized to 1. The regulator cannot use the exchange rate as an instrument to relax the external sector constraint.

3.1 Benchmark: No credit constraint

We analyze first, as a benchmark, the case in which the country is not credit-constrained, but information is still asymmetrically allocated. If the country is not credit-constrained, it can borrow to compensate any difference between the capital account and the trade account. So, the external sector does not impose any constraint on the amount of profits the firm can send to foreign owners. The only constraints the government has to consider are, then, incentive compatibility and participation constraints.

Invoking the revelation principle, the regulator can restrict attention to incentive compatible direct revelation regulatory contracts, that is, regulatory contracts in which the firm has to announce its marginal cost and has incentives to announce it truthfully.

In order to characterize the set of incentive compatible contracts, define

$$\pi_R\left(\widetilde{\theta},\theta\right) \equiv t\left(\widetilde{\theta}\right)+p_R\left(\widetilde{\theta}\right)q_R\left(p_R\left(\widetilde{\theta}\right)\right)-\theta q_R\left(p_R\left(\widetilde{\theta}\right)\right)-k, \tag{3}$$

$$\pi_R(\theta) \equiv \pi_R(\theta,\theta). \tag{4}$$

Then, incentive compatibility implies that telling the truth is a global maximum:

$$\theta\in\arg\max_{\widetilde{\theta}}\pi_R\left(\widetilde{\theta},\theta\right)\quad\forall\theta\in[\theta_L,\theta_H].$$

Using the envelop theorem, this translates into the first order incentive compatibility condition

$$\dot{\pi}_R(\theta)\equiv\frac{d\pi_R}{d\theta}(\theta)=-q_R(p_R(\theta))\quad\forall\theta\in[\theta_L,\theta_H], \tag{5}$$

and the (local) second order incentive compatibility constraint $\dot{q}_R(\theta)\leq 0$ guarantees that telling the truth is indeed a local maximum.

The single crossing condition is satisfied so these two constraints guarantee global incentive compatibility. Because we assume that shutting down is not an optimal policy, the contract has to satisfy also participation constraints whatever the type of the firm:

$$\pi_R(\theta) \geq \overline{\pi}, \quad \forall \theta \in [\theta_L, \theta_H]. \tag{6}$$

where $\overline{\pi}$ is the rent of investing anywhere else in the world.

According to equation (5), in any incentive compatible regulatory contract rents are decreasing in θ, so the only relevant participation constraint is

$$\pi_R(\theta_H) \geq \overline{\pi}. \tag{7}$$

Indeed, (5) and (7) imply that all the other participation constraints are satisfied.

In the next proposition, we describe the optimal regulatory contract when the country is not credit-constrained and discuss the effects of foreign ownership.

Proposition 1 *If the country is not credit-constrained, the optimal regulatory policy is given by* $\left(q_R^B(\theta), \pi_R^B(\theta)\right)$*, such that* $\forall \theta \in [\theta_L, \theta_H]$*,*

$$\pi_R^B(\theta) = \int_\theta^{\theta_H} q_R^B(\tau)\, d\tau + \overline{\pi}, \tag{8}$$

$$\frac{p_R^B(\theta) - \theta}{p_R^B(\theta)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta_R^B(\theta)} + \frac{1-\alpha+\lambda}{1+\lambda}\frac{F(\theta)}{f(\theta)}\frac{1}{p_R^B(\theta)}, \tag{9}$$

where

$$\eta_R^B(\theta) = -\frac{dq_R^B(\theta)}{dp_R}\frac{p_R^B(\theta)}{q_R^B(\theta)}, \quad q_R^B(\theta) = q_R\left(p_R^B(\theta)\right).$$

Quantities and rents are increasing in the proportion of domestic ownership.

Proof. The optimal regulatory policy solves the following problem:

$$\max \int_{\theta_L}^{\theta_H} \left[\begin{array}{l} V(q_R, q_T) + \lambda p_R q_R - p_T^d q_T - (1+\lambda)(\theta q_R + k) \\ -(1-\alpha+\lambda)\pi_R \end{array} \right] dF(\theta)$$

subject to

$$\dot{\pi}_R(\theta) = -q_R,$$

$$\pi_R(\theta_H) \geq \overline{\pi},$$

$$\dot{q}_R \leq 0.$$

The participation constraint of type θ_H is binding at the optimum because rents are costly for the regulator (the objective function is decreasing in π_R).

Integrating the incentive constraint and using the fact that $\pi_R(\theta_H) = \overline{\pi}$ we get:

$$\pi_R(\theta) = \int_{\theta}^{\theta_H} q_R(\tau)\, d\tau + \overline{\pi},$$

implying that

$$\int_{\theta_L}^{\theta_H} \pi_R(\theta)\, dF(\theta) = \int_{\theta_L}^{\theta_H} q_R(\theta) F(\theta)\, d\theta + \overline{\pi} = \int_{\theta_L}^{\theta_H} q_R(\theta) \frac{F(\theta)}{f(\theta)} dF(\theta) + \overline{\pi}.$$

Replacing in the regulator's objective function, the problem becomes

$$\max \int_{\theta_L}^{\theta_H} \left[\begin{array}{l} V(q_R, q_T) + \lambda p_R q_R - p_T^d q_T - (1+\lambda)(\theta q_R + k) \\ -(1-\alpha+\lambda) q_R \frac{F}{f} \end{array} \right] dF(\theta)$$

subject to

$$\dot{q}_R \leq 0.$$

We neglect the monotonicity constraint and we will check it ex post.

Using the fact that

$$\frac{\partial V}{\partial p_R} = u_R'(q_R(p_R)) \frac{\partial q_R}{\partial p_R} = p_R \frac{\partial q_R}{\partial p_R},$$

pointwise maximization with respect to p_R gives the following condition: $\forall\theta \in [\theta_L, \theta_H]$,

$$\frac{p_R^B(\theta)-\theta}{p_R^B(\theta)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta_R^B(\theta)} + \frac{1-\alpha+\lambda}{1+\lambda}\frac{F(\theta)}{f(\theta)}\frac{1}{p_R^B(\theta)}.$$

This is indeed the solution if the quantity profile is decreasing in θ (or the price profile is increasing), which is true given the monotone hazard rate property and the assumption that the marginal revenue is decreasing in q_R.

To prove the comparative static result, notice that, for any θ,

$$sign\left(\frac{dp_R(\theta)}{d\alpha}\right) = sign\left(\frac{\partial MDW}{\partial\alpha}\right) = sign\left(\frac{F(\theta)}{f(\theta)}\frac{\partial q_R}{\partial p_R}\right) < 0,$$

where MDW is the domestic welfare modified to incorporate the incentive constraint. So, the price is decreasing in α, meaning that quantities are increasing. Finally, rents increase when quantities increase, so rents also increase with α. ■

The first term in (9) is the Ramsey formula and corresponds to the mark-up over marginal costs that would be optimal if the regulator knew the value of θ. Under complete information some distortion is optimal because it helps saving on the cost of public funds. The second term is the distortion due to informational issues and it includes the effect of foreign ownership. As usual, the regulator will distort downward all quantities except the quantity assigned to the most efficient type, θ_L, in order to reduce informational rents. No type would like to pretend to be θ_L, so there is no gain in distorting this quantity.

The distortion is larger the smaller α. The proportion α measures how much the regulator values the rents given to the firm. The smaller α, the smaller the share of domestic capital and, therefore, the smaller the weight of rents in the domestic social welfare. As a consequence, the smaller α, the higher the cost in welfare terms of leaving rents.

Therefore, as α decreases, the benefit of reducing quantities in terms of lower rents increases and the regulator finds it optimal to increase distortions in order to reduce rents.

3.2 Optimal contract with credit rationing

In this section, we look at the more interesting case in which the country is credit-constrained. We keep the assumption of fixed exchange rate, but we assume now that the country has no access to external financing. If the country is credit-rationed, any deficit in the capital account must be compensated by a surplus in the trade account. The regulated firm has to send a share $(1-\alpha)$ of profits to its foreign owners.[2] This generates a deficit in the capital account. We assume that the country can accumulate foreign reserves but cannot borrow from foreign investors.

The country, then, faces the following constraint

$$(1-\alpha)\,\pi_R(\theta) \leq X, \quad \forall\theta \in [\theta_L, \theta_H]\,. \tag{10}$$

where X is the monetary value of exports. In this model, X is a constant from the regulator's viewpoint because the price of the tradable good is fixed in the international market and the demand for exports is only a function of the price.[3] This constraint

[2]For simplicity (basically, to save on the number of parameters of the model), we assume here that foreign owners send all their profits abroad and domestic owners keep all their profits inside the country. This is not an important assumption. The only thing we need for our argument is that some proportion of the profits of the regulated firm go out of the country.

[3]This is a simplifying assumption that allows us to make the point in a clear and crude way. In a more complete model, one can assume, for instance, that the demand for exports is a function of the quality of the good and that this variable can be in some way influenced by the government.

implies that the total amount of profits sent by the regulated firm to the foreign owners has to be smaller than the total monetary value of exports of the country *whatever the type of the firm*.

The effect of credit rationing is, thus, to introduce an upper bound on the rents the regulator can give to induce truthful revelation. This will have, of course, huge consequences in the optimal regulatory policy, because rents, at the end, are the only means the regulator has to give incentives to the firm to reveal its true marginal cost. In order to make the problem interesting we assume that $X < \pi_R^B(\theta_L)$, so the credit constraint is binding when the firm is efficient if the proportion of foreign ownership is high enough. Otherwise, the regulator could always implement the mechanism of Proposition 1 and the credit constraint would have no effect on the regulatory scheme. We also assume that $X > \overline{\pi}$, so that the set of implementable rent profiles is non-empty.

If α is close to 1, the credit constraint is not binding, because a very small proportion of profits is sent to foreign owners. So, Proposition 1 describes the optimal regulatory policy. Nevertheless, for any value of $X < \pi_R^B(\theta_L)$, there is a value $\alpha^*(X) \in [0,1]$ such that if $\alpha < \alpha^*(X)$, the credit constraint becomes binding: the benchmark solution does not satisfy the credit constraint for low values of θ. The regulator has to change the optimal contract in order to account for the constraint.

One could think that the optimal thing to do is to set the contract as in Proposition 1 for all types for which the credit constraint is not binding and then, fix the rent for efficient types at the value of the constraint. Even though this seems very intuitive, it goes against incentive compatibility and, therefore, cannot be implemented. Indeed, according to equation (5), the rent schedule has to be decreasing, because the regulator still wants the contract to be incentive compatible. Thus, the relevant credit constraint is

$$\pi_R(\theta_L) \leq \frac{X}{1-\alpha} \tag{11}$$

which, together with (5) implies that the credit constraint is satisfied for any possible value of the marginal cost.

INSERT FIGURE 1 ABOUT HERE

Figure 1 shows an example in which $\alpha < \alpha^*(X)$. Therefore, the benchmark contract, the contract without credit rationing, does not satisfy the credit constraint for any $\theta < \theta^*$. The regulator has to reduce all rents in order to satisfy both incentive compatibility and credit constraint.

Of course, in order to reduce rents in an incentive compatible way, the regulator has to distort further the quantities produced. In the next proposition, we show the optimal way to do it.

Proposition 2 *The optimal regulatory scheme when the country is credit-rationed is given by* $\left(q_R^C(\theta), \pi_R^C(\theta)\right)$ *such that* $\forall\theta \in (\theta_L, \theta_H]$

$$\begin{aligned}
\pi_R^C(\theta) &= \int_\theta^{\theta_H} q_R^C(\tau)\, d\tau + \overline{\pi}, && (12)\\
\frac{p_R^C(\theta)-\theta}{p_R^C(\theta)} &= \frac{\lambda}{1+\lambda}\frac{1}{\eta_R^C(\theta)} + \frac{1-\alpha+\lambda}{1+\lambda}\frac{F(\theta)}{f(\theta)}\frac{1}{p_R^C(\theta)} + \frac{\beta}{(1+\lambda)}\frac{1}{f(\theta)}\frac{1}{p_R^C(\theta)}, && (13)\\
q_R^C(\theta_L) &= q_R^B(\theta_L), && (14)\\
\pi_R^C(\theta_L) &= \begin{cases} \frac{X}{1-\alpha} & \text{and} \quad \beta > 0 \quad \text{if} \quad \frac{X}{1-\alpha} < \pi_R^B(\theta_L) \\ \pi_R^B(\theta_L) & \text{and} \quad \beta = 0 \quad \text{if} \quad \frac{X}{1-\alpha} \geq \pi_R^B(\theta_L) \end{cases}. && (15)
\end{aligned}$$

where $\beta \geq 0$ *is the multiplier of the credit constraint.*

Proof. The optimal regulatory policy solves the following problem:

$$\max \int_{\theta_L}^{\theta_H} DW\left(q_R(\theta), \pi_R(\theta), \theta\right) f(\theta)\, d\theta$$

subject to

$$\dot{\pi}_R(\theta) = -q_R(\theta), \quad \pi_R(\theta_H) = \overline{\pi}, \quad \pi_R(\theta_L) \quad \text{free},$$

$$\frac{X}{1-\alpha} - \pi_R(\theta) \geq 0, \quad \forall \theta \in [\theta_L, \theta_H].$$

The Hamiltonian of the problem is

$$\begin{aligned} H &= [V\left(p_R(q_R), p_T\right) + \lambda p_R(q_R) q_R - p_T q_T - (1+\lambda)\theta q_R \\ &\quad - (1-\alpha+\lambda)\pi_R] f(\theta) - \mu(\theta) q_R \end{aligned}$$

and the Lagrangian is

$$L = H + \xi(\theta)\left(\frac{X}{1-\alpha} - \pi_R(\theta)\right),$$

where $\mu(\cdot)$ is the adjoint variable associated with the incentive constraint and $\xi(\cdot)$ is the multiplier associated with the credit constraint.

Using the maximum principle we obtain that

$$\frac{\partial H}{\partial q_R} = \left[(1+\lambda)(p_R - \theta) + \lambda q_R \frac{dp_R}{dq_R}\right] f(\theta) - \mu(\theta) = 0, \tag{16}$$

$$-\frac{\partial L}{\partial \pi_R} = (1-\alpha+\lambda) f(\theta) + \xi(\theta) = \dot{\mu}(\theta), \tag{17}$$

$$\mu(\theta_L) = 0. \tag{18}$$

Moreover, the incentive constraint implies that the rent schedule is decreasing, meaning that $\xi(\theta) = 0 \ \forall \theta \in (\theta_L, \theta_H]$.

The existence of constraints on the state variable implies that we need to allow the adjoint variable μ to jump at θ_L. So, from (17) we have that for all $\theta \in (\theta_L, \theta_H]$

$$\mu(\theta) = (1-\alpha+\lambda) F(\theta) + \mu\left(\theta_L^+\right), \tag{19}$$

where

$$\mu\left(\theta_L^+\right)=\lim_{\theta\to\theta_L^+}\mu\left(\theta\right)=\mu\left(\theta_L\right)+\beta=\beta,$$

for some $\beta\geq 0$. Of course, if $\beta=0$ the function μ is continuous. Note also that condition (17) has to be satisfied only at points in which μ is continuous.

Suppose that $\beta=0$. Then, replacing (19) in (16) and rearranging terms gives that $\forall\theta\in[\theta_L,\theta_H]$

$$q_R^C\left(\theta\right)=q_R^B\left(\theta\right)\quad\text{and}\quad\pi_R^C\left(\theta\right)=\pi_R^B\left(\theta\right).$$

This is indeed the solution as long as the constraint is satisfied:

$$\frac{X}{1-\alpha}-\pi_R^B\left(\theta_L\right)\geq 0.$$

Otherwise, if

$$\frac{X}{1-\alpha}-\pi_R^B\left(\theta_L\right)<0$$

$\beta>0$ and the adjoint variable is discontinuous at θ_L. Moreover, for $\beta>0$, $q_R^C\left(\theta\right)$ is also discontinuous at θ_L and we obtain equations (12) to (15).

We still have to prove that the quantity profile is decreasing in θ. A sufficient condition for that is to have β small (the constraint is not too stringent) and/or the density function non-increasing (e.g., with a uniform distribution). ■

So, whenever the credit constraint is binding ($\beta>0$), quantities are further distorted from the benchmark case. The reason is that, in order to satisfy the credit constraint, the regulator is forced to reduce the rents for all types below θ^*. However, incentive compatibility implies that she has to reduce rents also for types above θ^* to avoid misreporting, because the rent profile has to be decreasing according to equation (5). On the other hand, incentive compatibility implies that the only means the regulator has to reduce rents is to reduce quantities.

An interesting (technical) point is that when the credit constraint is binding the optimal production profile is discontinuous at θ_L:

$$q_R^C\left(\theta_L\right) = q_R^B\left(\theta_L\right) > \lim_{\theta \to \theta_L^+} q_R^C\left(\theta\right).$$

Indeed, all quantities in the interval $(\theta_L, \theta_H]$ are reduced below the benchmark level in order to be able to reduce the rent of the most efficient type, and this new distortion is independent of the level of efficiency, because the credit constraint is also independent of θ. However, at θ_L it is costless to jump to the first best level of production because no rents have to be given to more efficient types. Moreover, the benefit of the jump is strictly positive because of the increase in allocative efficiency. Therefore, assigning the first best production to the most efficient type is always optimal. The optimal production schedule is depicted in Figure 2. Notice, however, that because types are continuous the probability of observing a θ_L firm is actually equal to 0. In a discrete type case, it is easy to verify that the production of the most efficient type is always first best. For an illustration with 2 types, see Section 4.1. Incentive compatibility, on the other hand, implies that the rent profile has to be continuous. Therefore, we have that

$$\pi_R^C(\theta_L) = \frac{X}{1-\alpha} = \int_{\theta_L}^{\theta_H} q_R^C(\theta) d\theta = \lim_{\theta \to \theta_L^+} \pi_R^C(\theta).$$

INSERT FIGURE 2 ABOUT HERE

Proposition 3 *If the multiplier of the credit constraint, β, is positive, it decreases with the value of exports X and with the exchange rate e. For any θ, $q_R^C(\theta)$ increases with these two parameters.*

Proof. Equation (12) is satisfied for any X. Therefore,

$$\frac{\partial \pi_R^C}{\partial X}(\theta) = \int_\theta^{\theta_H} \frac{\partial q_R^C}{\partial X}(\tau)\, d\tau \quad \forall \theta \in [\theta_L, \theta_H].$$

According to equation (15) and the fact that the rent is continuous

$$\frac{\partial \pi_R^C}{\partial X}(\theta_L) = \int_{\theta_L}^{\theta_H} \frac{\partial q_R^C}{\partial X}(\theta)\, d\theta = \frac{1}{(1-\alpha)} > 0.$$

Combining these two things, we have that

$$\exists \hat{\theta} : \frac{\partial q_R^C}{\partial X}\left(\hat{\theta}\right) > 0.$$

Differentiating equation (13) for $\hat{\theta}$ we obtain that

$$\frac{\partial}{\partial q_R^C}\left[(1+\lambda)\left(p_R^C - \hat{\theta}\right) + \lambda \frac{\partial p_R^C}{\partial q_R^C} q_R^C\right] \frac{\partial q_R^C}{\partial X} f\left(\hat{\theta}\right) = \frac{\partial \beta}{\partial X}. \tag{20}$$

The first term is negative because of the second order condition, implying that

$$\frac{\partial \beta}{\partial X} < 0.$$

Moreover, conditions (13) and (20) are true for any θ and β is independent of θ. This implies that, for any θ

$$\frac{\partial q_R^C}{\partial X}(\theta) > 0.$$

With the same development we show that

$$\begin{aligned} \frac{\partial \pi_R^C}{\partial e}(\theta_L) &= \frac{1}{1-\alpha}\left(X - e\frac{\partial q_T}{\partial e}\right) > 0, \\ \frac{\partial \beta}{\partial e} &= \frac{\partial}{\partial q_R^C}\left[(1+\lambda)\left(p_R^C - \hat{\theta}\right) + \lambda \frac{\partial p_R^C}{\partial q_R^C} q_R^C\right] \frac{\partial q_R^C}{\partial e} f\left(\hat{\theta}\right) < 0. \end{aligned}$$

■

The multiplier β is a decreasing function of the value of exports and the exchange rate, because both higher exports and a higher exchange rate relax the credit constraint, increasing the rents the regulator can offer to the firm.

The effect of the proportion of domestic ownership on the multiplier is ambiguous. Since the upper bound on the rents increases with α, it can be shown that the quantity profile must increase with α for some values of θ. Moreover, it can be shown that if $\frac{\partial q_R^C}{\partial \alpha}(\theta^*) > 0$ it must be that $\frac{\partial q_R^C}{\partial \alpha}(\theta) > 0$ for any $\theta > \theta^*$. This implies that the quantity profile increases with the proportion of domestic ownership when the firm is relatively inefficient. When the firm is low cost, the sign of $\frac{\partial q_R^C}{\partial \alpha}(\theta)$ cannot be determined in general. In fact, if there is some value of θ for which the quantity profile decreases with α, then the multiplier β increases with α. Nevertheless, overall efficiency, as measured by domestic social welfare always increases with α.

Of course, the fact that β is positive is completely associated with the asymmetry of information. Indeed, if the regulator knew the firm's marginal cost, no type of firm would receive a rent above the outside option, $\overline{\pi}$ and, therefore, there would be no need to distort quantities. Indeed, in that case, the credit constraint in not binding whatever the values of α and θ.

4 Flexible exchange rate

The government can get an additional degree of freedom by playing with the exchange rate. In particular, a devaluation increases the domestic value of exports (or decreases the foreign value of profits) and, therefore, relaxes the credit constraint.

Suppose the tradable sector produces with a constant return to scale technology but its production is limited by a fixed resource, L, say land. This implies that

$$y_T = q_T + x_T \leq L.$$

where y_T is the local production of tradable goods. Exports are then limited by the size of the resource. If the country wants to relax the credit constraint increasing exports, it has to induce a decrease in the local consumption of the tradable good, which is done by increasing its price through the devaluation. Devaluation has then two positive effects on the credit constraint. It increases the value of each exported unit and increases the units exported because it reduces domestic consumption. To guarantee an equilibrium in the resource market, it must be that the price of the tradable good equals the price of land, w. This gives the equilibrium condition:

$$ep_T = w.$$

This implies, in particular, that any devaluation increases the profits of the land owners, via the increase of the price of land.

Of course, the government has to bear in mind that any devaluation has a negative impact on domestic welfare coming from two different fronts. On the one hand, it increases the domestic price of tradable goods, reducing the consumer surplus. On the other hand, the domestic value of the outside option of the firm increases with the exchange rate, so the whole profit profile has to move upwards in order to satisfy the new participation constraint. In particular, the participation constraint writes now:

$$\pi_R(\theta) \geq e\overline{\pi}.$$

The new credit constraint is

$$(1-\alpha)\,\pi_R(\theta) \leq eX(e)\,, \quad \forall\theta \in [\theta_L, \theta_H]\,, \tag{21}$$

with

$$X(e) = p_T (L - q_T(e)),$$

and we normalize the international price to $p_T = 1$.

We assume that the monetary authority is in charge of fixing the exchange rate. The regulator, on the other hand, designs the regulatory contract. We model a sequential game between these two government agencies. The monetary authority is the leader, and chooses the exchange rate taking into account the effects of her decision on the regulatory contract. Having observed the exchange rate fixed by the monetary authority (which determines the credit constraint), the regulator chooses the contract. Since we are not interested in looking at conflicts inside the government, we assume that both agencies are interested in maximizing domestic social welfare.[4] The idea behind this timing is that there are some general rules (like the monetary policy) which are fixed in advanced because the government pretends to influence other agents' decisions. More particular rules (like regulatory contracts) are designed following these general rules.

In order to incorporate all the effects of a change in the exchange rate, we assume that devaluating the currency entails a cost $C(e)$, increasing and convex in e. For instance, suppose that agents in this country have a stock of debt expressed in foreign currency. Then, a higher exchange rate increases the value of the external debt, which affects the agents' welfare in a negative way. We do not explicitly model such an effect, but it is certainly not negligible in reality.[5]

[4]Given that the tradable and regulated sectors are independent in this model, except for their link through the credit constraint, we would obtain the same result by assuming that the regulator is concerned only with domestic social surplus within the regulated sector itself.

[5]Imagine that D is the stock of foreign debt, measured in foreign currency. The value of this debt in

We define $\eta_T = -\frac{dq_T}{de}\frac{e}{q_T}$, the elasticity of domestic demand of the tradable good with respect to the exchange rate. In the next proposition we obtain the optimal exchange rate and the optimal regulatory policy.

Proposition 4 *a) The optimal exchange rate is given by e^* such that*

$$e^* \left[C'(e^*) + (1-\alpha+\lambda)\overline{\pi}\right] = \beta\left(\frac{\eta_T(e^*)\, q_T(e^*) + X(e^*)}{1-\alpha} - \overline{\pi}\right) + e^* X(e^*) \tag{22}$$

b) The optimal regulatory contract is the same as in Proposition 2 and the only effect of the exchange rate on the incentive scheme is through the value of the multiplier, β.

Proof. We solve the game backwards. Given the exchange rate fixed by the monetary authority, the regulator chooses a regulatory contract, $(q_R(\theta,e), \pi_R(\theta,e))$ to maximize social welfare. Since the exchange rate has no direct impact on the regulatory contract, except through the multiplier β, the contract is the same as in Proposition 2: $(q_R^C(\theta,e), \pi_R^C(\theta,e))$. Moreover, given Proposition 3, we know that the quantity profile is increasing in the exchange rate and β is decreasing in the exchange rate. Knowing this, the monetary authority chooses the exchange rate that maximizes domestic social welfare.

First, remember that the exchange rate modifies the domestic price of the tradable goods:

$$p_T^d = ep_T = e,$$

which affects itself the demand for tradable goods.

The Lagrangian function is now:

$$L = \int_{\theta_L}^{\theta_H} \left[\begin{array}{l} V\left(q_R^C, q_T\right) + \lambda p_R\left(q_R^C\right) q_R^C - (1+\lambda)\,\theta q_R^C - eq_T - C(e) \\ -(1-\alpha+\lambda)\left(q_R^C \frac{F}{f} + e\overline{\pi}\right) + wL + \beta\left(\frac{X(e)}{1-\alpha} - \frac{q_R^C}{ef} - \overline{\pi}\right) \end{array}\right] dF(\theta)$$

local currency is eD. To make this payment, the government has to raise taxes for a value of $(1+\lambda)eD$. The cost of the devaluation in this case is $C(e) = (1+\lambda)eD$. For other motivations of the cost of the devaluation, see Diaz-Alejandro (1963), Krugman and Taylor (1978) and Solimano (1986).

and the monetary authority chooses e knowing that $w = e$.

The first order conditions with respect to the exchange rate (assuming an interior solution) are

$$\frac{\partial L}{\partial q_R^C}\frac{d\, q_R^C}{d\, e} + \frac{\partial L}{\partial \beta}\frac{d\, \beta}{d\, e} + \frac{\partial L}{\partial e} = 0.$$

Now, given that the regulator maximizes social welfare under the same constraints, the optimal regulatory contract is such that

$$\frac{\partial L}{\partial q_R^C} = \frac{\partial L}{\partial \beta} = 0.$$

Therefore, the first order conditions reduce to

$$\int_{\theta_L}^{\theta_H} \left[\begin{array}{c} V_e\left(q_R^C, q_T\right) - q_T - e\frac{dq_T}{de} - (1-\alpha+\lambda)\,\overline{\pi} \\ +L + \frac{\beta}{1-\alpha}\frac{dX(e)}{de} + \beta\frac{q_R^C}{e^2 f} - C'(e) \end{array} \right] dF(\theta) = 0.$$

We know that

$$V_e\left(q_R^C, q_T\right) = e\frac{dq_T}{de}(e) \text{ and } \frac{dX}{de}(e) = -\frac{dq_T}{de}(e),$$

so the optimal exchange rate satisfies

$$\int_{\theta_L}^{\theta_H} \left[-q_T - (1-\alpha+\lambda)\,\overline{\pi} + L - \frac{\beta}{1-\alpha}\frac{dq_T}{de} + \beta\frac{q_R^C}{e^2 f} \right] dF(\theta) = C'(e)\,.$$

Now, using the constraint, we know that

$$\int_{\theta_L}^{\theta_H} \beta\frac{q_R^C(\theta)}{e^2 f(\theta)} dF(\theta) = \frac{\beta}{e^2}\int_{\theta_L}^{\theta_H} q_R^C(\theta)\, d\theta = \frac{\beta}{e}\left(\frac{X(e)}{1-\alpha} - \overline{\pi}\right).$$

The optimal exchange rate is then implicitly defined by[6]

$$e^*\left[C'(e^*) + (1-\alpha+\lambda)\,\overline{\pi}\right] = \beta\left(\frac{\eta_T(e^*)\, q_T(e^*) + X(e^*)}{1-\alpha} - \overline{\pi}\right) + e^* X(e^*)\,.$$

■

[6] The second order condition is satisfied if the demand function for tradable goods and/or the function $C(e)$ are convex enough.

The interpretation of condition (22) is straightforward. Increasing the exchange rate has a cost in terms of lower consumer surplus, because the domestic price of tradable goods is higher and in terms of an increase in the outside option of the firm. The marginal cost of increasing the exchange rate, in domestic currency is

$$e\left[C'(e) + q_T + (1-\alpha+\lambda)\,\overline{\pi}\right].$$

The marginal benefit of devaluating is given by the increase in the upper bound on profits that can be sent by foreign owners of the firm evaluated in domestic currency (given by the multiplier, β) plus the increase in the profits of the tradable sector:

$$\beta\left(\frac{\eta_T q_T + X}{1-\alpha} - \overline{\pi}\right) + eL.$$

So, the optimal exchange rate is such that the marginal cost is equal to the marginal benefit.

4.1 An illustration: The two-type case

To give a better idea of the effects of the credit constraint on the optimal contract, consider the following example. Assume that

$$\theta \in \{\theta_L, \theta_H\} \text{ and } \Pr(\theta = \theta_L) = \nu.$$

The regulator, then maximizes the expected domestic social welfare, defined by

$$\begin{aligned}
&\nu\left[V\left(q_R^L, q_T\right) + \lambda p_R\left(q_R^L\right) q_R^L - (1+\lambda)\,\theta_L - (1-\alpha+\lambda)\,\pi_R^L\right] \\
&+ (1-\nu)\left[V\left(q_R^H, q_T\right) + \lambda p_R\left(q_R^H\right) q_R^H - (1+\lambda)\,\theta_H - (1-\alpha+\lambda)\,\pi_R^H\right] \\
&- e q_T + wL - C(e),
\end{aligned}$$

where $q_R^i = q_R(\theta_i)$ and $\pi_R^i = \pi_R(\theta_i)$ for $i = L, H$ and $w = e$.

The relevant constraints are the incentive constraint of an efficient firm, the participation constraint of an inefficient firm and the credit constraint:

$$\begin{aligned} \pi_R^L &\geq \pi_R^H + \Delta\theta q_R^H, \quad (\gamma) \\ \pi_R^H &\geq e\overline{\pi}, \quad (\mu) \\ \tfrac{e(L-q_T)}{(1-\alpha)} &\geq \pi_R^L. \quad (\beta) \end{aligned}$$

Maximizing with respect to quantities and rents, the other first order conditions are

$$\begin{aligned} \gamma - \beta &= \nu(1-\alpha+\lambda), \\ \mu - \gamma &= (1-\nu)(1-\alpha+\lambda), \\ \frac{p_R\left(q_R^L\right)-\theta_L}{p_R\left(q_R^L\right)} &= \frac{\lambda}{1+\lambda}\frac{1}{\eta_R\left(q_R^L\right)}, \\ \frac{p_R\left(q_R^H\right)-\theta_H}{p_R\left(q_R^H\right)} &= \frac{\lambda}{1+\lambda}\frac{1}{\eta_R\left(q_R^H\right)} + \frac{\gamma\Delta\theta}{(1-\nu)(1+\lambda)p_R\left(q_R^H\right)}. \end{aligned}$$

Both γ and μ are strictly positive, meaning that the incentive constraint of a good type and the participation constraint of a bad type are both binding. The credit constraint may or may not be binding. Suppose that it is not, i.e. $\beta = 0$. This implies that $q_R^H = q_H^B$ defined by

$$\frac{p_R\left(q_H^B\right)-\theta_H}{p_R\left(q_H^B\right)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta_R\left(q_H^B\right)} + \frac{\nu(1-\alpha+\lambda)\Delta\theta}{(1-\nu)(1+\lambda)p_R\left(q_H^B\right)}$$

and this is the solution as long as the credit constraint is satisfied:

$$q_H^B \leq \frac{e}{\Delta\theta}\left(\frac{L-q_T}{1-\alpha} - \bar{\pi}\right).$$

Otherwise, the constraint is binding, $\beta > 0$ and

$$q_R^H = \frac{e}{\Delta\theta}\left(\frac{L-q_T}{1-\alpha} - \bar{\pi}\right).$$

From the first order conditions we have that there is no distortion for the efficient type and the intuition for this result is the same as in the continuous case. On the other hand, the distortion for the inefficient type, which is positive because the incentive constraint is binding, can be written

$$\frac{\gamma\Delta\theta}{(1-\nu)(1+\lambda)\,p_R\left(q_R^H\right)}=\frac{\left[\nu\left(1-\alpha+\lambda\right)+\beta\right]\Delta\theta}{(1-\nu)(1+\lambda)\,p_R\left(q_R^H\right)} \tag{23}$$

and increases with the multiplier of the credit constraint, β.[7] The qualitative results are, therefore, the same as in the case of continuous types. The optimal contract is represented in Figure 3.

INSERT FIGURE 3 ABOUT HERE

If the country is not credit-constrained, the optimal regulatory policy would be to set $q_H = q_H^B$. However, the rent that has to be given to the efficient firm is too high and the credit constraint becomes binding. Therefore, the regulator is forced to fix the profit of the efficient firm at the value of exports, implying that, in order to keep incentives, the quantity produced by the inefficient firm has to be reduced to q_H^C. The quantity produced by the efficient firm is still the first-best quantity, because there are no gains in reducing it.

From the first order conditions with respect to the exchange rate we obtain

$$\beta q_T\left(\sigma\left(e\right)+\eta_T\left(e\right)\right)=\left(1-\alpha\right)\left(\mu\overline{\pi}-q_T\left(e\right)\sigma\left(e\right)+C'\left(e\right)\right),$$

[7] In this two-type case, it is clear that there is no distortion for the bad type under complete information, *even if the country is credit-constrained*, because in that case both γ and β are equal to 0.

where $\sigma(e) = \frac{L}{q_T(e)} - 1 \geq 0$ is the ratio of exports on domestic consumption and measures the export effort of the country.[8]

5 Concluding remarks

In this paper we have developed a model of optimal regulation in a small open economy subject to credit constraints. The model is especially relevant for developing countries in which the regulated sector plays an important role and foreign investments in the regulated sector are non-negligible. In such a context, credit constraints have a negative effect on the overall efficiency of the regulated sector beyond the traditional effect coming from the need to provide enough incentives. Indeed, the country is obliged to reduce production in the regulated sector below the (incentive compatible) efficient levels in order to satisfy both incentive and credit constraints.

The credit constraint puts an upper bound on the level of profits the regulated firm can send abroad to foreign owners, determined by the value of net exports. This limits the rents the regulator can give to the firm in order to obtain truthful revelation. The government is then obliged either to reduce efficiency in the regulated sector or to promote exports in order to relax the credit constraint.

This model constitutes an attempt to include some general equilibrium effects in the optimal regulation analysis. This is not a general equilibrium model, but it makes the link between regulation and the external sector. In particular, we show that the

[8]Without credit constraints, the optimal exchange rate is such that $\mu\overline{\pi} + C'(e) = q_T(e)\,\sigma(e)$, so the optimal exchange rate is higher when the country is credit-constrained.

design of the optimal regulatory policy cannot be independent of the performance of the external sector if the country has not access to the international credit markets. Moreover, the design of a tight monetary policy associated with a fixed exchange rate has an important impact on the (optimal) distortions introduced in regulation. This is true even in a model in which the tradable and non-tradable sectors are not related neither technologically nor through preferences.

We have made many simplifying assumptions in order to make the model tractable and be able to draw neat conclusions. First, we have assumed that foreign investors send all their profits abroad. This is generally not true, since a proportion of the profits may be reinvested in the same firm or even in other sectors at the local level. In this sense, the credit constraint may not be so tight. However, some domestic investors may want to invest part of their share of the profits in foreign assets, increasing the capital outflows. In any case, it is likely that during periods of financial distress for the country (that is, when the credit constraint becomes relevant), investors (both domestic and foreign) are more willing to move their capital to safer places. Second, we have left aside any dynamic considerations by looking at a static model. In reality, dynamic issues are very important in these kinds of problems, even abstracting from renegotiation issues. If the firm turns out to be inefficient and thus earns low rents, the government would be able to accumulate international reserves to be used to relax the credit constraint in the following period. Finally, in order to isolate the effects of the credit constraint, we have modelled the tradable and regulated sectors as completely independent, both in consumption and in production. Of course, accounting for crossed effects is an important matter. For instance, many regulated firms produce public utilities, used as inputs by all other firms, including the producers of tradable goods. If the credit constraint induces lower production of public utilities, this will have a negative impact on the production of tradable goods, worsening the ability of the country to generate foreign currency.

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Figures

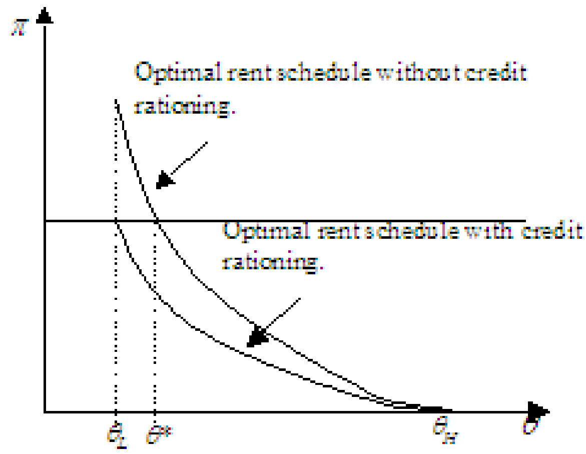

Figure 1: Effects of the credit constraint on the optimal rent schedule

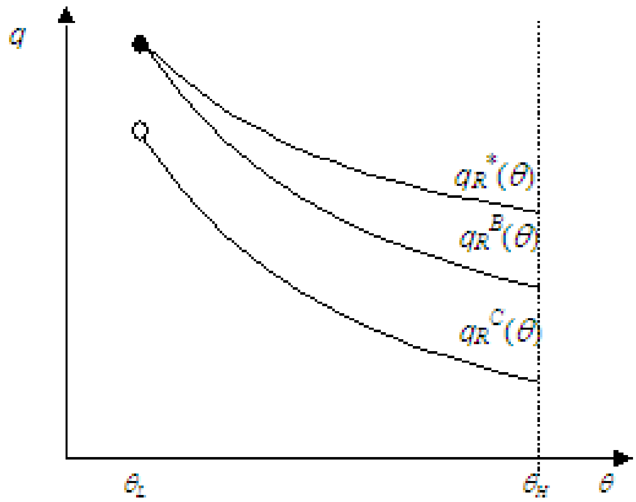

Figure 2: Effects of the credit constraint on the optimal production schedule

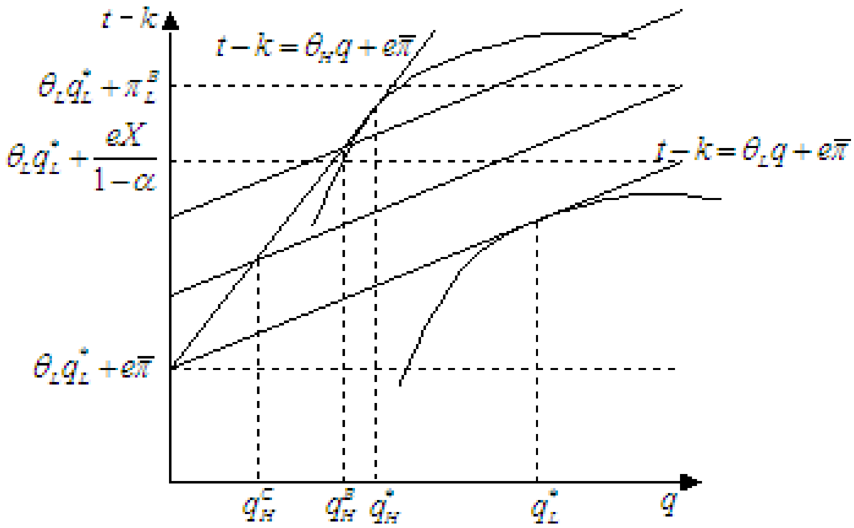

Figure 3: Optimal contract with credit constraint and 2 types