Optimal Domestic Regulation under Asymmetric Information and International Trade : A Simple General Equilibrium Approach*

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ABSTRACT: This paper investigates the design of domestic incentive regulation under asymmetric information in the general equilibrium context of an open economy. We discuss the implications of such incentive regulation for international specialization and the conditions for trade openness to be still welfare-improving. More specifically, we append to an otherwise standard 2×2 Heckscher-Ohlin model of a small open economy a continuum of intermediate sectors producing non-tradable goods used in tradable sectors. Those goods are produced by local firms which are privately informed on their technologies but are regulated by a domestic regulator. Even when domestic regulation is optimally designed at the sectoral level, asymmetric information induces allocative distortions which cannot be corrected and have a general equilibrium impact. The small country becomes relatively richer in the factor which is informationally sensitive so that asymmetric information might reverse patterns of trade. Free trade is Pareto-dominated by autarky when it exacerbates the distortions due to asymmetric information. As an aside, we derive a *constrained First Welfare Theorem* under asymmetric information of general interest beyond our international trade model.

KEYWORDS: Incentive regulation, trade, specialization, asymmetric information.

JEL CLASSIFICATION: D82; F12; L51.

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1 Introduction

One of the founding principles of Neoclassical Trade Theory is that free trade improves welfare under perfect competition, in the absence of externality, and when markets are complete. Of course, economists have long been aware that this result may fail when any of those conditions no longer holds. Still, the common wisdom remains that, with enough policy instruments to correct for domestic distortions, a small economy always benefits from open borders.

This paper reconsiders this general principle in a framework where asymmetric information remains a fundamental obstacle to the correction of domestic distortions. A basic tenet of the Incentive Regulation literature[1] is indeed that efficiency and redistributive concerns are deeply linked under asymmetric information. Any regulatory policy aimed at correcting allocative distortions which could be necessary to enjoy the full the gains from trade has necessarily strong distributional consequences between those agents who retain private information and those who remain uninformed. This basic principle stands in sharp contrast with the common wisdom held by international economists that, in the absence of frictions in redistributing the gains from trade, free trade is an optimal policy regime for a small open economy.

With those conflicting insights in mind, this paper traces out the implications of asymmetric information within domestic markets for the degree of international competitiveness and the choice of specialization faced by a small open country. Embedding the lessons of the Incentive Regulation literature into a general equilibrium environment, we discuss the interaction between trade integration and optimal domestic regulation. In particular, we ask whether trade openness remains welfare-improving compared to autarky when asymmetric information is a fundamental obstacle to the design of efficient domestic regulations.

More specifically, we consider a small open economy with two factors (capital and labor) and two final goods. Those goods are traded on international markets and produced by competitive sectors. In this typical Hecksher-Ohlin environment, one of the final good sectors is capital intensive while the other is instead labor intensive. Those sectors also use some non-tradable intermediate inputs which are produced domestically. One may think of those inputs as local non-traded services, telecommunication, energy, transportation, etc... Each of those intermediate sectors is run by a local monopolist which, for simplicity, uses capital (maybe under the form of infrastructures) as its sole input. Owners of those monopolies have private information on their technologies. Insights from the Incentive Regulation literature[2] indicate that those owners

[1] Laffont and Tirole (1993) and Laffont and Martimort (2002) for instance.

[2] Baron and Myerson (1982), Laffont and Tirole (1993), Armstrong and Sappington (2005) among

may withdraw some information rent from being privately informed. To correct the distortions due to market power and informational asymmetries, regulation of those intermediate sectors is needed. However, any such regulation remains by and large constrained by the fact that regulators lack complete information.

Our first contribution is to show how asymmetric information in regulated non-traded sectors affects the pattern of specialization of this small country. We emphasize two effects at play in explaining changes in the pattern of trade.

First, inducing information revelation from privately informed firms requires to give up costly information rents[3] which increase with production. Optimal regulation reduces thus information rents by downsizing production in regulated sectors. Since these sectors use capital only, more capital flows towards the capital intensive good that is traded on the international market. This makes that good relatively cheaper to produce. With asymmetric information, everything happens as if the small country was relatively richer in the factor which is informationally sensitive. This first effect may change the pattern of trade with the rest of the world compared with the case of complete information.

Second, in a general equilibrium framework, information rents end up being pocketed by a (representative) consumer and boost demands for tradable goods. *In fine*, this consumer enjoys not only his income associated to the usual factor endowments but also the equivalent of an *"informational endowment"* reflecting the factor content of information rents captured by intermediate sectors. With Cobb-Douglas preferences, this additional wealth effect does not change the relative demand for tradable goods.[4] The pattern of trade is thus entirely dictated by the lower production cost of the capital intensive good due to the "informationally induced" output contraction in intermediate sectors.

Our second contribution consists in assessing the normative implications of free trade under asymmetric information. A priori, there are now two possible sources of distortions in our small open economy. First, monopolies in intermediate sectors might have market power and charge a mark-up. Second, asymmetric information might also affect the allocation of resources. The first distortion could easily be fixed under complete information by means of convenient subsidies. In such a highly hypothetical context, free trade would always dominate autarky for a small open economy. The conventional wisdom that well-designed "behind-the-border" regulatory policies do no conflict with free trade would prevail. Asymmetric information is a more seri-

others.

[3]Laffont and Tirole (1993) and Laffont and Martimort (2002, Chapter 2) for instance.

[4]With non-homothetic preferences, the general equilibrium income effect of information rents would also create a demand channel through which asymmetric information would affect trade patterns.

ous concern even when the largest set of regulatory policies is available. Asymmetric information is indeed the source of a mark-up that remains even *after* policy intervention. Given the dead-weight loss associated to those distortions, free trade may not always dominate autarky.

We delineate the conditions under which free trade dominates autarky even under asymmetric information. However, free trade can now be sometimes *inferior to autarky*. The intuition is quite simple. To minimize information rents in intermediate sectors, the optimal regulations of those sectors reduce their output. If trade openness induces a pattern of specialization which reinforces this domestic distortion, this additional distortion may outweigh the traditional gains from trade. Free trade is then dominated by autarky.

This paper lies at the the intersection of the Trade and Regulation literatures and borrows insights from both.

First, we build on the classical Incentive Regulation literature as developed by Baron and Myerson (1982), Laffont and Tirole (1993) and Armstrong and Sappington (2005) among others. One important insight from that literature is the fact that, under asymmetric information, there is always a fundamental trade-off between reducing the costly information rents of regulated firms and reaching allocative efficiency. Although this literature has proved to be particularly useful in assessing sectoral interventions, it remains cast in a very partial equilibrium framework. As such, it does not address the role that sectoral regulations may have on the whole economy. Our analysis extends this line of research to a simple general equilibrium context of a small open economy. We give a particular attention to the role played by information rents in a general equilibrium environment. We emphasize the allocative consequences for the whole economy of having sectoral regulatory policies that redistribute wealth from informed agents (shareholders or managers of firms) to uninformed agents (consumers or clients). We also analyze the effects of such costly redistribution on prices and trade patterns. These are clearly important issues given on the one hand the current trend towards globalization and, on the other hand the increasing role that domestic regulated sectors such as local transportation, telecommunications, electricity, utilities and various accounting and financial services play in shaping the competitiveness and production pattern of countries. In this sense, our paper contributes to a better understanding of how "behind-the-border" regulations affect patterns of specialization and trade.

Our work is also directly related to the trade literature that assesses how trade openness interacts with domestic distortions.[5] Following Bhagwati (1971)'s taxonomy, dis-

[5]For earlier contributions, see Bhagwati, Ramaswami and Srinavasan (1969), Kemp and Negishi (1969), Bhagwati (1971) and Srinavasan (1987) for instance.

tortions found in the absence of non-pecuniary externalities might arise from market imperfections or from misguided policy interventions which are exogenously set. In both cases, this literature emphasizes that well-designed targeted policies could avoid the domestic distortion and reestablish the optimality of free trade for a small open economy. In a similar vein, exogenous market incompleteness was also found to be a significant impediment to the benefit of open trade (Newbery and Stiglitz, 1984, Eaton and Grossman, 1985). Dixit (1987, 1989a, 1989b) extended this line of research by deriving endogenously the degree of incompleteness of markets from moral hazard or adverse selection problems in insurance markets. These papers showed that trade policy should not be used when governments can rely on policy instruments (insurance policies) directly targeted towards the informational issue under scrutiny. In our framework, asymmetric information creates also a basic source of distortions. Incentive compatibility constraints limit the set of feasible allocations even when the most complete set of regulatory policy instruments is available. Distortions are not exogenous but instead deeply linked to the underlying information structure that constrains instruments and policies.

This last point is in fact closely related to a burgeoning literature that incorporates incomplete contracts, agency or transaction costs in the general equilibrium context of international trade. Ju and Wei (2005) have introduced moral hazard for firms looking for external finance in a Heckscher-Ohlin environment. Sectors for which capital is rationed because of the agency problem may expand more as the financial sector develops. Acemoglu, Antras and Helpman (2007) and Levchenko (2007) have investigated how the quality of institutions affects trade patterns. Institutions quality is modelled as an exogenous index of the incompleteness of contracts. Better institutions reduce the hold-up problem faced by owners of specific capital and the extra compensation (the rent) that they must receive ex-ante for bearing that deadweight loss.[6] In a model with asymmetric information as ours, the deadweight loss of contracting and the rent hold by informed parties is not due to contract incompleteness but comes from incentive compatibility constraints. Asymmetric information makes it possible to analyze the normative properties of the competitive equilibrium as we show below, a task that has been so far left aside by the existing literature.

Finally, the rent-efficiency trade-off that is the concern of our paper and its general equilibrium consequences also bears some similarities with the efficiency-equity trade-

[6]Levchenko (2008) has endogenized this quality index by appending a lobbying model where factor owners lobby over the quality of institutions. Grossman and Helpman (2002a, 2002b), Antras (2003, 2005) and Marin and Verdier (2003, 2009) have all used the same incomplete contracts environment à la Grossman and Hart (1986) or Aghion and Tirole (1997) to generate inefficiencies in trade international models. However, the focus of those papers is mainly on the boundaries of and the allocation of power within firms in an international trade context.

off which has been studied in the literature on optimal redistributive taxation in open economies (Feenstra and Lewis, 1991, Hoff 1994, Naiko 1996, Gabaix 1997a, 1997b, Guesnerie 1998, 2001, Spector 2001). These authors have investigated how asymmetric information imposes limits on domestic redistributive policies in open economies. Extending the framework developed by Stiglitz (1982) to a 2×2 trade model, they showed that free-trade can be socially inferior, at least locally, to autarky. In these papers, the demand side of the economy has private information on the source of factor income (skilled versus unskilled labor income) and incentive compatibility constraints affect the trade-off between consumption and leisure. Our model of optimal regulation investigates instead informational asymmetries on the production side of the economy. In such a context, domestic regulatory intervention also involves a trade-off between allocative efficiency in the use of inputs and rent extraction in privately informed monopolistic sectors. Focusing however on the production side makes our welfare analysis much more tractable, a step which is important to derive a more global analysis. Moreover, it facilitates and highlights our derivation of a *constrained First Welfare Theorem* which is of independent and broader interest. The competitive equilibrium of the economy under asymmetric information also solves the problem faced by a social planner problem when feasibility constraints are conveniently modified to account for "informational endowments". No such result was available in the literature on taxation in open economy quoted above. Beyond our specific trade model, our methodology can certainly be used elsewhere to derive welfare properties of competitive equilibria under asymmetric information.

Section 2 describes both the domestic and international sides of the economy. Section 3 discusses the benchmark economy under complete information. Section 4 considers an economy with asymmetric information. It starts with a characterization of the autarkic equilibrium and goes on by characterizing how patterns of trade with the rest of the world are affected by informational asymmetries. Section 5 considers the normative implications of openness. Section 6 concludes. Proofs are relegated to an Appendix.

2 The Model

Our model has two building blocks. The first block describes trade between a small economy and the rest of the world. The second one analyzes the design of optimal regulation for intermediate sectors within that country. On the trade side, we consider a standard Heckshser-Ohlin model with two tradable goods, manufactures M and agricultural products A, and two factors, labor and capital. On top of these standard features, we add a continuum of intermediate sectors run by domestic monopolies which use only capital as an input.[7] One can think of those non-tradable inputs as electricity, telecommunication, transportation and utilities which are produced locally, regulated, and not traded on international markets. Those examples show that capital (generally under the form of infrastructures) is the main input for producing intermediate goods and this aspect will be a key point of our modeling.

Production technologies in intermediate sectors are highly idiosyncratic and owners of those firms have private information on their characteristics. Because of natural barriers to entry, competition by potential entrants in those sectors is of little value in the short-run. Domestic regulation is the only device to limit market power. Even though regulators face no restriction in their choice of instruments to curb market power, such intervention is nevertheless constrained by their incomplete knowledge of production technologies.

We analyze each building block in turn and we describe the equilibrium under autarky. Then, we introduce market openness and analyze its role on domestic regulation and the pattern of trade.

• **Preferences.** To simplify the analysis and make it as tractable as possible, consumers have preferences over consumptions of tradable goods M and A given by a standard Cobb-Douglas utility function:

$$U(C_M, C_A) = \alpha ln C_M + (1-\alpha) ln C_A \quad \text{where } \alpha \in (0,1).$$

• **Intermediate Sectors.** There exists a continuum of intermediate sectors indexed by the subscript j which varies continuously on $[0,1]$.[8] Producing x_j units of intermediate good j requires $\theta_j x_j$ units of capital.[9] The productivity of each intermediate sector j is affected by a random shock θ_j. Over the whole continuum of sectors, these shocks are independently and identically distributed on a set $\{\underline{\theta}, \bar{\theta}\}$ with respective probabilities ν and $1-\nu$. Those probabilities are common knowledge. Let $\underset{\theta}{E}(\cdot)$ be the expectation operator w.r.t. θ.

Firms in the intermediate sectors produce more when they are hit by a good shock $\underline{\theta}$ than by a bad shock $\bar{\theta}$. Accordingly, we shall refer in the sequel to a firm with parameter

[7]Given the symmetry of our model, all conclusions are reversed if intermediate sectors use only labor.

[8]The assumption of a continuum of intermediate sectors is made for tractability only. Later on, it allows us to use the Law of Large Numbers to simply characterize optimal regulation in those sectors and to define an aggregate productivity index that parameterizes the whole economy. (A more cumbersome analysis could be done with a finite number of sectors.) With such a formulation, all non-tradable intermediate inputs enter symmetrically in the production of the tradable sectors. Breaking this symmetry leads to a more complex analysis without changing the main insights of the paper.

[9]Our assumption that services are produced with capital only and that the manufacturing and agriculture sectors use either labor or capital but not both is just made for analytical convenience. What matters are the relative intensities in these three sectors and, especially in our context, which of the two tradable sectors uses more intensively the input factor also used in the regulated sectors.

$\underline{\theta}$ (resp. $\bar{\theta}$) as efficient (resp. inefficient).

Production shocks in sector j are observed only by firm j's owners. This assumption is motivated by the fact that the technology for each intermediate sector is highly specific to that sector and cannot be easily compared with technologies for producing other intermediate inputs.[10]

Without regulation, firms in the intermediate sectors would fix prices above their marginal costs. Such market power calls for regulatory policies that could improve allocative efficiency by shifting down prices closer to marginal costs and increasing demand of the final sector for the intermediate products. However, asymmetric information in intermediate sectors still creates important trade-offs between allocative efficiency and extraction of the monopolies' information rents even when an optimal regulation is designed.

We denote $t_{jM}(\theta_j)$ and $t_{jA}(\theta_j)$ the payments made by the final sectors to intermediate sectors to obtain the inputs needed for production. Profits in the intermediate sector j can be written as:

$$U_j(\theta_j) = t_{jM}(\theta_j) + t_{jA}(\theta_j) - r\theta_j(x_{jM}(\theta_j) + x_{jA}(\theta_j)), \quad \text{for } j \in [0, 1].$$

To ensure that firms in the intermediate sectors break-even, the regulatory payments received by those firms must cover their costs. This yields the condition $U_j(\theta_j) \geq 0$.

• **Final Sectors.** The final goods M and A are produced by competitive firms. We denote by p the price of the manufactured good whereas the agricultural good is taken as the numeraire. Each final sector uses a continuum of intermediate non-tradable inputs and production factors. In lines with standard trade factor endowment theory, we assume that sector M is capital intensive while sector A is labor intensive. More precisely, the production functions in each sector are respectively given by

$$Y_M = D_M^{\beta} K^{1-\beta} \quad \text{and} \quad Y_A = D_A^{\beta} L^{1-\beta},$$

where $\beta \in (0, 1)$ and $D_i = \left(\int_0^1 x_{ji}^{\frac{\sigma-1}{\sigma}} dj\right)^{\frac{\sigma}{\sigma-1}}$ and where the amount of intermediate good j used in the final sector i is denoted by x_{ji} for $i = M, A$. The elasticity of substitution σ between any two intermediate goods in the production process of good i is such that $\sigma > 1$.

[10]The reader may find our representative customer a little bit schizophrenic. On the one hand, as an owner of the intermediate sectors, he is privately informed on the shocks hitting each of these sectors. On the other hand, as an owner of the firms in the final sector and a consumer, he ignores this piece of information. This modeling difficulty can easily be avoided by considering different classes of owners knowing different pieces of information but having the same Cobb-Douglas utility function. There would be as many classes as intermediate sectors. Using Gorman aggregation rule, it is standard to show that the behavior of those agents can be aggregated and summarized by the behavior of a single representative agent having the whole endowment of the economy.

This small economy is endowed with respectively $\bar{L}$ units of labor and $\bar{K}$ units of capital. Let r be the rental rate of capital and w the wage.

Profits in each final good sector can thus be written respectively as:

$$\Pi_M = p\left(\int_0^1 x_{jM}^{\frac{\sigma-1}{\sigma}} dj\right)^{\frac{\beta\sigma}{\sigma-1}} K^{1-\beta} - rK - \int_0^1 t_{jM}(\theta_j)dj$$

and

$$\Pi_A = \left(\int_0^1 x_{jA}^{\frac{\sigma-1}{\sigma}} dj\right)^{\frac{\beta\sigma}{\sigma-1}} L^{1-\beta} - wL - \int_0^1 t_{jA}(\theta_j)dj.$$

Under asymmetric information, it is a significant loss of generality to restrict the payments of the final sectors to be linear in the quantity of intermediate goods they buy. Menus of contracts are indeed useful devices to screen informed parties according to their private information. We discuss below the precise form of those incentive payments. For the time being, it is only useful to see those payments as being decided by the regulator in charge of regulating intermediate sectors.

• **Regulatory Objectives.** To model a meaningful trade-off between efficiency and rent extraction, we assume that the uninformed regulatory agency in charge with curbing market power in the intermediate sectors maximizes a weighted sum of the profits in the intermediate sectors and the profits of the final goods sectors which use intermediate goods in their own production process, namely:

$$W = \Pi_M + \Pi_A + \zeta \int_j U_j(\theta_j)dj \tag{1}$$

where $\zeta \in [0, 1]$.

This objective function is directly inspired from the Incentive Regulation literature.[11] In the limiting case where $\zeta = 1$, the regulatory agency gives an equal weight to both the final and the intermediate sectors. Then, the regulator does not care about the distribution of the surplus between uninformed and informed parties in the economy. The equilibrium allocations will be the same whether we have asymmetric or complete information as we shall see below. More interestingly, when ζ is less than one, the weight given to the intermediate sectors is lower. Our analysis below reveals that such situations lead to an important trade-off between efficiency and rent extraction.

The regulator takes final goods prices and factor prices as given when designing an optimal regulation. In other words, the regulator has no direct tools to influence what happens on the final sector. This fits with regulatory policies used in practice for

[11]Baron and Myerson (1982), Laffont and Tirole (1993), Armstrong and Sappington (2005). Baron (1989) endogenizes the choice of ζ as resulting from a median-voter choice in Congress. For the purpose of our analysis, we will keep that parameter as given.

electricity, telecommunication or transports where regulatory agencies have restricted sectoral objectives directly related to the interests of customers of those regulated sectors (here the tradeable sectors). There is still significant scope for unregulated prices to clear supply and demand in competitive sectors even after regulatory tools have been designed.

Although his objective incorporates the profits of firms in the final sector, the regulator does not introduce any distortion in the relationship with consumers. Instead, his sole concern is to reduce as much as possible distortions due to the intermediate firms' behavior. Indeed, under complete information, the regulator would like to ensure that intermediate sectors charge a price equal to marginal cost so that production decisions in the final sectors are not distorted. There would be no obstacle to design an efficient regulation moving those prices closer to marginal costs by means of well designed per-unit output subsidies.

Under asymmetric information, moving prices towards marginal costs must be done while still respecting incentive compatible so that the regulator does not increase unduly subsidies. Incentive compatibility may conflict with the regulator's redistributive concerns between final and intermediate sectors. This will induce some distortions and a wedge between price and marginal cost in intermediate sectors.

Expressing profits in the final sector as a function of the information rents of the intermediate ones, the regulator's objective function can indeed be rewritten as:

$$\underbrace{p\left(\int_0^1 x_{jM}^{\frac{\sigma-1}{\sigma}}\,dj\right)^{\frac{\beta\sigma}{\sigma-1}} K^{1-\beta} + \left(\int_0^1 x_{jA}^{\frac{\sigma-1}{\sigma}}\,dj\right)^{\frac{\beta\sigma}{\sigma-1}} L^{1-\beta} - wL - r\left(\int_0^1 \theta_j(x_{jM}+x_{jA})dj + K\right)}_{\text{Allocative Efficiency}}$$

$$-(1-\zeta)\underbrace{\int_0^1 U_j(\theta_j)dj}_{\text{Information Rents}}.$$

This expression stresses the trade-off faced by the regulator. On the one hand, the regulator is concerned by an efficient use of resources, namely finding the vector of inputs (K, L, x_{jM}, x_{jA}) which maximizes aggregated profits in all production sectors (first bracketed term). On the other hand, the regulator is also interested in minimizing the information rents left to the intermediate sectors as soon as $\zeta < 1$.

3 Trade and Regulation under Complete Information

The case of complete information provides a useful benchmark against which one can assess how asymmetric information might change trade patterns.

• **Supply Side.** Suppose that the regulator is fully informed on the whole vector of shocks $\vec{\theta} = (\theta_1, \ldots, \theta_j, \ldots)$ hitting intermediate sectors. Given that there is a continuum of symmetric intermediate sectors, the Law of Large Number applies and we have:

$$D_i = \left[\int_0^1 x_{ji}^{\frac{\sigma-1}{\sigma}} dj\right]^{\frac{\sigma}{\sigma-1}} = \left(\underset{\theta}{E}\left(x_{ji}(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\sigma}{\sigma-1}} \quad i = M, A,$$

where $x_{ji}(\theta)$ is the output of the intermediate goods j for sector i when the productivity shock hitting this sector is θ. Because of symmetry, all sectors produce the same outputs in equilibrium when they are hit by similar shocks. Therefore, the index j can be omitted and we can denote $x_{ji}(\theta) = x_i(\theta)$ for any θ. Similarly, we also denote by $U(\theta)$ the profit or information rent of a given intermediate sector when it is hit by shock θ.

Under complete information, the regulator's problem is thus given by:

$$\max_{\{K,L,x_i(\cdot),U(\cdot)\}} p\left(\underset{\theta}{E}\left(x_M(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\beta\sigma}{\sigma-1}} K^{1-\beta} + \left(\underset{\theta}{E}\left(x_A(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\beta\sigma}{\sigma-1}} L^{1-\beta}$$

$$-wL - rK - r\underset{\theta}{E}\left(\theta(x_M(\theta) + x_A(\theta))\right) - (1-\zeta)(\nu U(\underline{\theta}) + (1-\nu)U(\bar{\theta}))$$

$$\text{subject to } U(\theta) \geq 0, \text{ for all } \theta \text{ in } \{\underline{\theta}, \bar{\theta}\} \tag{2}$$

where (2) are the firms' participation constraints in the intermediate sectors.[12]

Solving this problem is straightforward. The corresponding solution characterizes the supply side of this economy when regulation takes place under complete information.

Proposition 1 *Under complete information, the optimal domestic regulation of the intermediate sectors entails the following properties.*

• *For any realization of the productivity shock, firms in the intermediate sectors get zero information rent:*

$$U^{FI}(\theta) = 0, \quad \textit{for all } \theta \textit{ in } \{\underline{\theta}, \bar{\theta}\}.$$

• *Zero-profit conditions in the final sectors yield*

$$r^\beta w^{1-\beta} = (1-\beta)^{1-\beta}\beta^\beta\Theta^{-\beta} \tag{3}$$

[12]Note again that the prices are taken as given by the regulator since he is only concerned by transactions between the final and the intermediate sectors. We nevertheless slightly abuse and simplify notations by omitting the dependence of the optimization variables on the price vector.

and

$$p = \omega^{-(1-\beta)} \tag{4}$$

where $\Theta = \left(\underset{\theta}{E}(\theta^{1-\sigma})\right)^{\frac{1}{1-\sigma}}$ *is an aggregate productivity index and* $\omega = \frac{w}{r}$ *is the relative factor price.*

Under complete information, the optimal regulation of the supply side of the economy maximizes the whole profit of the vertically integrated structure obtained by merging final and intermediate sectors. Everything happens as if intermediate sectors were selling their inputs at marginal cost to final good producers and were making zero profit. Because of constant returns to scale, the whole profit of this integrated structure will also be zero.

Importantly, (3) defines a downward sloping curve, $r = r_1^{FI}(w)$ which captures the zero profit condition on the agricultural sector under constant returns to scale: a higher wage must be compensated by a lower cost of capital. We will refer to that curve as the *zero profit locus*.

The parameter Θ reflects the productivity of this economy. As Θ increases, production of intermediate goods out of capital becomes more difficult. This decreases the demand for complementary inputs, capital and labor, emanating from the final sectors.

• **Demand Side.** Given the Cobb-Douglas preferences of the representative consumer, demands for both consumption goods are respectively

$$C_M = \frac{\alpha R^{FI}}{p} \quad \text{and} \quad C_A = (1-\alpha)R^{FI},$$

where R^{FI} is the consumer's total income under complete information. With constant returns to scale in the production sectors, this income comes from the factor endowment only and $R^{FI} = w\bar{L} + r\bar{K}$.

• **Autarky.** Under autarky, the equilibrium conditions on the agricultural and labor markets yield

$$(1-\alpha)(w\bar{L} + r\bar{K}) = X_A^{\beta}\bar{L}^{1-\beta} = \frac{w}{1-\beta}\bar{L}$$

where the second equality comes from expressing labor demand in the agricultural sector. This can be simplified as:

$$\frac{1}{\omega} = \frac{r}{w} = \frac{\bar{L}}{\bar{K}}\left(\frac{1}{(1-\alpha)(1-\beta)} - 1\right). \tag{5}$$

Those market clearing conditions define thus an upward sloping relationship $r = r_2^{FI}(w)$ linking the rental rate of capital and the labor wage: *the autarky locus*. The relative factor price ω is inversely proportional to the relative endowment of factors. As capital becomes more scarce, the rental rate of capital appreciates in relative terms.

An *autarky equilibrium* is obtained when (3), (4) and (5) hold altogether. Next proposition ensures existence of such an equilibrium and provides useful comparative statics.

Proposition 2 *There exists a unique competitive equilibrium under autarky and complete information. It is characterized by the price system (p^{FI}, w^{FI}, r^{FI}) solving (3), (4) and (5).*

As Θ increases, the zero-profit locus $r_1^{FI}(\cdot)$ is shifted downwards and the autarky locus $r_2^{FI}(\cdot)$ remains unchanged. There is a downward shift in the factor prices w^{FI} and r^{FI}.

As the productivity index deteriorates (i.e., Θ increases), the demand for intermediate goods decreases and demands for both capital and labor diminish. This leads to a lower rental rate of capital and lower wages. (See Figure 1.) Since intermediate sectors enter the same way in the production technologies of both tradable sectors, the whole impact of a change in the productivity index comes from a shift in the zero-profit locus (3). When the productivity index increases, the autarky locus (5) is unchanged and the relative factor price remains the same, namely $\frac{\bar{L}}{\bar{K}}\left(\frac{1}{(1-\alpha)(1-\beta)}-1\right)$. In the sequel, we will be particularly interested in the impact of asymmetric information on the productivity index.

• **Free Trade.** Let us now consider the case where this small country opens up trade with the rest of the world. Under free trade, the relative price of final goods is fixed on the world market at some exogenous level p. Note that (3) and (4) are still valid so that all remaining prices in the open economy are completely defined.

Define the representative consumer's indirect utility function $V^{FI}(p)$ as follows:

$$(\mathcal{P}^{FI}): \quad V^{FI}(p) \equiv \max_{\{C_M, C_A, X_M, X_A, x_m(\cdot), x_a(\cdot)\}} \alpha lnC_M + (1-\alpha)lnC_A \text{ subject to}$$

$$pX_M^{\beta}K^{1-\beta} + X_A^{\beta}\bar{L}^{1-\beta} \geq pC_M + C_A \tag{6}$$

$$X_M = \underset{\theta}{E}\left(x_M^{\frac{\sigma-1}{\sigma}}(\theta)\right)^{\frac{\sigma}{\sigma-1}} \tag{7}$$

$$X_A = \underset{\theta}{E}\left(x_A^{\frac{\sigma-1}{\sigma}}(\theta)\right)^{\frac{\sigma}{\sigma-1}} \tag{8}$$

$$\bar{K} = K + \underset{\theta}{E}\left(\theta(x_M(\theta) + x_A(\theta))\right). \tag{9}$$

Constraint (6) is a trade-balance condition whereas (7), (8) and (9) are standard feasibility conditions for goods M, A and capital respectively.

From the First Welfare Theorem, $V^{FI}(\cdot)$ is also the consumer's utility when domestic markets for input factors are competitive. The solution to $(\mathcal{P}^{FI})$ replicates indeed the competitive equilibrium. By definition, $V^{FI}(\cdot)$ is thus minimum at p^{FI} such that the markets for final goods are on autarky (i.e., $C_M = X_M^{\beta} K^{1-\beta}$ and $C_A = X_A^{\beta} \bar{L}^{1-\beta}$) since indeed imposing those extra conditions corresponds to a more constrained optimization. Therefore, free trade is always welfare superior.

More formally, let us denote by $\gamma(p)$ the non-negative multiplier of the trade-balance condition (6) at world price p. The Envelope Theorem yields:

$$\dot{V}^{FI}(p) = \gamma(p) \left(X_M^{\beta}(p) K^{1-\beta}(p) - C_M(p) \right)$$

where the dependence of all variables on the market price p is made explicit. Of course, that right-hand side is precisely worth 0 at p^{FI} since domestic production is equal to domestic consumption under autarky. Going into more details and using the specific Cobb-Douglas preferences, we can easily compute

$$V^{FI}(p) = \alpha ln \alpha + (1-\alpha) ln(1-\alpha) - ln\gamma(p) - \alpha ln p$$

where

$$\frac{1}{\gamma(p)} = R^{FI} = \beta^{\beta}(1-\beta)^{1-\beta}\Theta^{-\beta}\left(p\bar{K} + p^{-\frac{\beta}{1-\beta}}\bar{L}\right).$$

Finally, $V^{FI}(\cdot)$ is minimized for

$$p^{FI} = \left(\frac{\bar{L}}{\bar{K}}\left(\frac{1}{(1-\alpha)(1-\beta)} - 1\right)\right)^{1-\beta}. \tag{10}$$

Under complete information, one recovers the traditional result that, once domestic regulation is optimally designed, free trade is always Pareto-superior to autarky.

Patterns of trade. When the world price differs from p^{FI}, two cases are possible.

• $p > p^{FI}$. The world price of manufacturing goods is greater than under autarky. The small country exports good M which is capital intensive and imports good A which is labor intensive final good. Increasing p increases the demand for capital and raises its rental rate above its autarky level. At the same time, the wage rate decreases to guarantee zero profit in the final sectors under constant returns to scale: $w < w^{FI}$ and $r > r^{FI}$.

• $p < p^{FI}$. The world price for M is lower than its value under autarky. By symmetry, we get: $w > w^{FI}$ and $r < r^{FI}$.

Figure 1 below summarizes graphically the two cases.

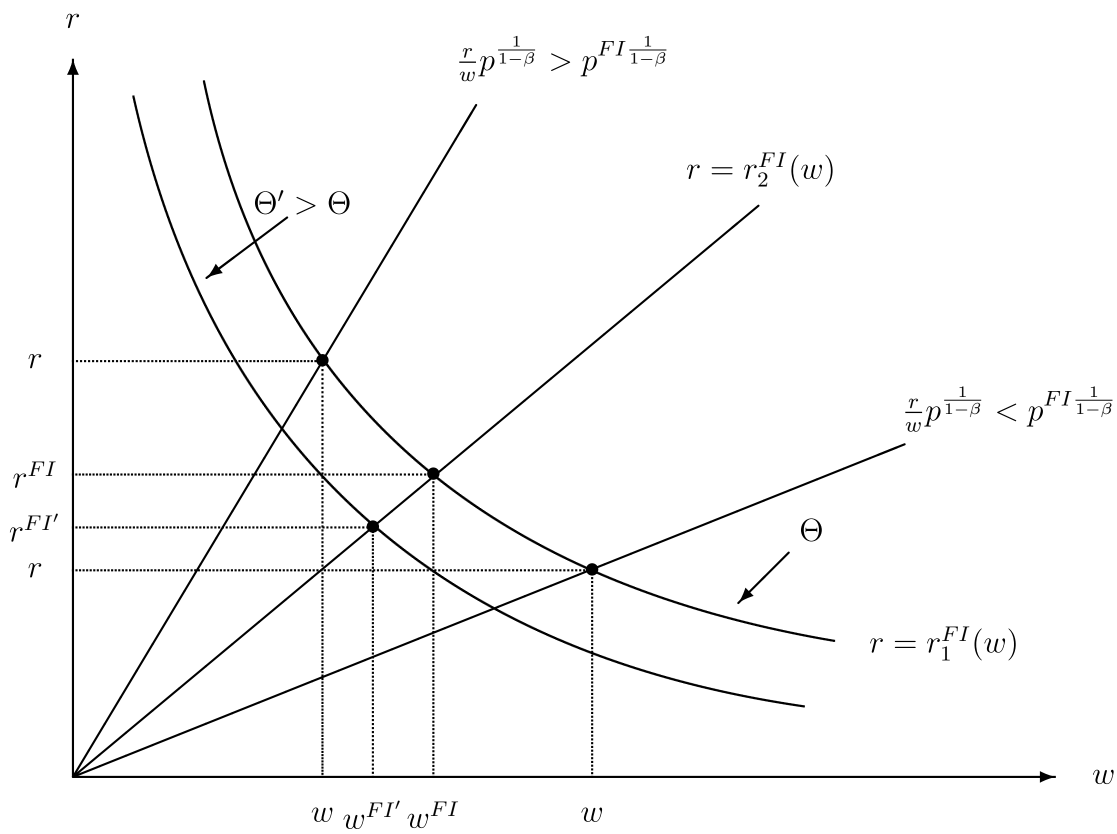

Figure 1: Autarky and free-trade equilibria under complete information.

4 Trade and Regulation under Asymmetric Information

Consider now the case of asymmetric information. Owners of firms in the intermediate sectors are privately informed on the productivity shocks that hit those sectors.

• **Supply Side.** Productivity shocks in any intermediate sector are not observed by the regulator. Incentive regulation induces firms in those sectors to truthfully reveal their productivity parameters.

From the Revelation Principle,[13] such incentive scheme stipulates how much each

[13]Myerson (1982).

intermediate sector has to produce as a function of its announcement on its efficiency shock. In full generality, and given that production in the final sectors depends on the whole vector of input factors produced by intermediate sectors, the transfer t_j and the output x_j in sector j should also depend on the whole vector of announcements $\vec{\hat{\theta}}$ made by each sector. Given that there is a continuum of symmetric intermediate sectors with i.i.d. shocks, we will use the Law of Large Numbers to approximate the optimal contract by a vector of incentive contracts for each sector which depend only on the announcement of that sector. We thus envision a collection of bilateral regulatory contracts for each sector which take the form $\{t(\hat{\theta}), x(\hat{\theta})\}_{\hat{\theta}\in\{\underline{\theta},\bar{\theta}\}}$ where $\hat{\theta}$ is the announced productivity parameter in that sector, $t(\hat{\theta})$ and $x(\hat{\theta})$ being respectively payment and production for that sector.

The set of direct revelation incentive feasible mechanisms above is the largest possible one from the point of view of the regulator in charge of solving the informational problem in the intermediate sectors. For instance, this set contains direct revelation mechanisms that replicate what the regulator could achieve by setting a specific subsidy on the production of those sectors. Indeed, such (indirect) mechanisms can simply be subsumed as a linear scheme of the form $T(x) = tx$ that applies equally well to any firm in any intermediate sector j irrespective of its efficiency parameter. Such schemes admit the following representation as direct revelation mechanisms $\{t(\hat{\theta}) = tx(\hat{\theta}), x(\hat{\theta})\}_{\hat{\theta}\in\{\underline{\theta},\bar{\theta}\}}$. Leaving firms in their intermediate sectors unregulated and letting them charge their monopoly prices gives also an allocation that can be replicated with a direct mechanism as described above. Of course, more complex schemes may be entertained as we will see below.[14]

It is a by-now standard result[15] that, in two types adverse selection models, the binding incentive constraint at the optimum is that of an efficient firm $\underline{\theta}$ whereas the binding participation constraint is that of an inefficient firm $\bar{\theta}$. Still, using symmetry

[14] It is worth mentioning that taxes, subsidies and more general transfers schemes based on the capital used as input of those intermediate sectors cannot be implemented by the regulator. Such schemes require indeed that the regulator observes this amount of capital $\theta_j x_j$ used by firm j and that its is verifiable by third-parties. Given that the output x_j delivered by this firm in the intermediate sector j is also supposed to be observable, the regulator could infer θ_j in that case so that asymmetric information would not be an issue. An unpalatable conclusion. A more complex model allowing the observability of both the output and the input in the intermediate sectors could be constructed by introducing some nonverifiable managerial effort along the lines of Laffont and Tirole (1993). For instance, the firm in sector j can improve its efficiency by exerting some effort e_j (counted in units of labor) at the cost we_j, so that the final parameter becomes $\theta_j - \eta(e_j)$ for some $\eta(\cdot)$ increasing and convex. Even when knowing both input and output in this intermediate sector, the regulator cannot disentangle the impact of effort and innate efficiency on final efficiency so that asymmetric information and the associated information rents remain a concern. We leave the analysis of such extension for future research although intuition grasped from the regulation literature (Laffont and Tirole, 1993) shows that the insights we develop below are to a large extent robust.

[15] Laffont and Martimort (2002, Chapter 2) for instance.

among all sectors, those constraints can be written respectively as

$$U(\underline{\theta}) \geq t_M(\bar{\theta}) + t_A(\bar{\theta}) - r\underline{\theta}\left(x_M(\bar{\theta}) + x_A(\bar{\theta})\right) = U(\bar{\theta}) + r\Delta\theta\left(x_M(\bar{\theta}) + x_A(\bar{\theta})\right), \quad (11)$$

$$U(\bar{\theta}) \geq 0. \quad (12)$$

Under asymmetric information, the regulator's problem becomes:

$$\max_{\{K,L,x_i(\cdot),U(\cdot)\}} p\left(\underset{\theta}{E}\left(x_M(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\beta\sigma}{1-\sigma}} K^{1-\beta} + \left(\underset{\theta}{E}\left(x_A(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\beta\sigma}{1-\sigma}} L^{1-\beta}$$

$$-wL - rK - r\underset{\theta}{E}\left(\theta(x_M(\theta) + x_A(\theta))\right) - (1-\zeta)(\nu U(\underline{\theta}) + (1-\nu)U(\bar{\theta}))$$

subject to (11) and (12).

Since the last two constraints are binding at the optimum, the agency costs coming from asymmetric information can be identified with the positive amount of expected information rent that must be left to efficient firms in the intermediate sectors, weighted by the factor $1-\zeta$, namely

$$(1-\zeta)\nu U(\underline{\theta}) = r\nu(1-\zeta)\Delta\theta\left(x_M(\bar{\theta}) + x_A(\bar{\theta})\right).^{16}$$

These agency costs are proportional to the production of inefficient firms in the intermediate sectors. This is where the trade-off between allocative efficiency and distribution becomes crucial: the more production is requested from the intermediate sectors, the more information rent must be left to those sectors.

Inserting this expression of these agency costs into the regulator's objective function, one can easily see that everything happens as if the regulator's optimization problem was the same as under complete information with the only change coming from the fact that the true productivity parameter $\bar{\theta}$ is now replaced by a so-called *virtual productivity parameter* $\tilde{\bar{\theta}}_\zeta = \bar{\theta} + (1-\zeta)\frac{\nu}{1-\nu}\Delta\theta$ which is greater. At the same time, the virtual productivity of the efficient firm is kept unchanged $\tilde{\underline{\theta}}_\zeta = \underline{\theta}$. As a result, we can directly import our previous results from Proposition 1 to characterize the supply side of this economy.

Proposition 3 *Under asymmetric information, the optimal regulation of the intermediate sectors entails the following properties.*

• *Firms in the intermediate sectors get a positive information rent if and only if they are hit by a good productivity shock $\underline{\theta}$;*

$$U^{AI}(\underline{\theta}) = r\Delta\theta(x_M^{AI}(\bar{\theta}) + x_A^{AI}(\bar{\theta})) \text{ and } U^{AI}(\bar{\theta}) = 0.$$

[16] Remember again that those optimization variables depend on the equilibrium price vector but this dependence has been omitted for notational simplicity.

• *(4) still holds whereas (3) is replaced by*

$$r^{\beta}w^{1-\beta}(1-\beta)^{\beta}\beta^{\beta}\tilde{\Theta}_{\zeta}^{-\beta} \tag{13}$$

where the virtual productivity index $\tilde{\Theta}_{\zeta} = \left(E(\tilde{\theta}_{\zeta}^{1-\sigma})\right)^{\frac{1}{1-\sigma}}$ *is now greater than the full information productivity index* Θ *and closer to* Θ *as* ζ *increases towards 1.*

Under asymmetric information, the regulator wants to reduce the incentives of $\underline{\theta}$ firms in the intermediate sectors to report being less efficient than what they are. To induce participation by the least efficient firm $\bar{\theta}$, the regulator must increase the overall payments from the final sectors for the inputs produced by those firms. This increases the incentives of an efficient firm to pretend being less efficient and reap such large payments. If it does so, it can produce the same output as an inefficient firm by using less capital and enjoy the high price the latter receives. Owners of efficient firms receive then a positive information rent as can be seen from (11).

Those information rents are perceived as costly by the regulator as soon as ζ is less than one, and more so the closer to zero it is. However, this cost can be reduced by simply requesting less production $x_M(\bar{\theta})$ and $x_A(\bar{\theta})$ than under complete information (keeping the rental price of capital as given). That extra distortion amounts to an implicit tax on inefficient firms which is formally captured by replacing $\bar{\theta}$ and Θ respectively by their virtual values $\tilde{\bar{\theta}}_{\zeta}$ and $\tilde{\Theta}_{\zeta}$. Because of asymmetric information, everything happens as if there were now a wedge between the unit price at which inefficient firms in the intermediate sectors can sell their goods and their marginal cost. Output is inefficiently low for those firms. This is more so the smaller ζ, as the regulator expresses less concern for efficient firms in the intermediate sectors. Asymmetric information creates a deadweight loss in the economy. Moreover, because information rents are proportional to the rental rate of capital, the deadweight loss increases with r. This latter effect is particularly important for what follows.

Asymmetric information does not change the overall trend between the rental price of capital and labor wage. The zero-profit condition for final sectors (13) still yields a curve $r = r_1^{AI}(w)$ which is still downward sloping exactly as under complete information. Asymmetric information replaces nevertheless the productivity index by a greater virtual productivity index. The curve (13) is shifted downwards below (3). Overall, zero-profit is obtained at lower prices for capital and labor.

There is a second effect of asymmetric information in a general equilibrium model. Information rents in the intermediate sectors are indeed also redistributed to the representative consumer as owner of intermediate sectors. That consumer enjoys thus income flows not only from the standard capital and labor endowments in this economy but also from an additional *"informational endowment"*. In other words, the proceeds of the implicit tax that asymmetric information imposes on the production of inefficient firms are pocketed by the representative consumer who owns intermediate sectors.

• **Demand Side.** Under asymmetric information, the total endowment of the representative consumer can be then written as:

$$R^{AI} = \underbrace{w\bar{L} + r\bar{K}}_{\text{Standard Endowment}} + \underbrace{r\nu\Delta\theta(x_M^{AI}(\bar{\theta}) + x_A^{AI}(\bar{\theta}))}_{\text{Informational Endowment}} . \tag{14}$$

Using the expressions of the intermediate sectors outputs given in the Appendix (Equation (A10)), we get:

$$R^{AI} = (w\bar{L} + r\bar{K})\left(1 + \frac{\mu\lambda}{1+\mu}\right) \tag{15}$$

where $\lambda = \frac{\nu\Delta\theta\tilde{\bar{\theta}}_{\zeta}^{-\sigma}}{\nu\underline{\theta}^{1-\sigma}+(1-\nu)\bar{\theta}\tilde{\bar{\theta}}_{\zeta}^{-\sigma}}$ and $\mu = \frac{\beta}{1-\beta}\left(\frac{\nu\underline{\theta}^{1-\sigma}+(1-\nu)\bar{\theta}\tilde{\bar{\theta}}_{\zeta}^{-\sigma}}{\nu\underline{\theta}^{1-\sigma}+(1-\nu)\tilde{\bar{\theta}}_{\zeta}^{1-\sigma}}\right)$.

Everything happens thus as if, because of his informational endowment, the true income perceived by the representative customer was now *scaled up* by a factor $1 + \frac{\mu\lambda}{1+\mu}$. Thanks to Cobb-Douglas preferences, such change in revenue does not affect the relative demand for the two final goods, it modifies only their magnitudes.

For the rest of the paper, we will assume that the following condition holds:

Assumption 1

$$\frac{1}{(1-\alpha)(1-\beta)} > 1 + \frac{\mu\lambda}{1+\mu}.$$

Tedious computations show that this condition is always satisfied when $\Delta\theta$ is small enough, i.e., when the adverse selection problem is not too significant. Assumption 1 ensures existence of a a competitive equilibrium as we see below.[17]

4.1 Autarky

We are now ready to characterize the equilibrium prices under autarky. Market clearing conditions on the agricultural and labor markets yield:

$$(1-\alpha)R^{AI} = X_A^{\beta}\bar{L}^{1-\beta} = \frac{w}{1-\beta}\bar{L}$$

[17] Had it not hold, asymmetric information would be incompatible with competitive behavior. Intuitively, consumers may want to take into account the impact their demand has on the part of their revenue that comes from holding shares in sectors enjoying information rents. We leave the analysis of this interesting case for further research.

where the second equality comes from expressing labor demand in the agricultural sector. Using the expression for R^{AI} given in (15), we obtain:

$$\frac{1}{\omega} = \frac{r}{w} = \frac{\bar{L}}{\bar{K}} \left(\frac{1}{(1-\alpha)(1-\beta)\left(1+\frac{\mu\lambda}{1+\mu}\right)} - 1 \right). \tag{16}$$

When Assumption 1 holds, the market equilibrium equation (16) still defines an *autarky locus under asymmetric information* $r = r_2^{AI}(w)$ which is upward sloping.

However, $r_2^{AI}(\cdot)$ is always below $r_2^{FI}(\cdot)$. The intuition comes from a careful analysis of the supply and demand curves on the agricultural market. First, remember that the representative consumer's income is scaled up under asymmetric information. Therefore, the demands for both final goods increase and, given the Cobb-Douglas preferences, they do so at the same rate. This income effect is captured by the scale factor $1 + \frac{\mu\lambda}{1+\mu}$ on the l.h.s. of (16). Second, production on the agricultural market is proportional to labor wages exactly as under complete information and (up to changes in the equilibrium level of wages) is unchanged. Hence, equilibrium on the agricultural market can only be obtained when the rental rate of capital decreases so that the demand boost due to the income effect is compensated by a decreased in income from factor endowments.[18]

We can now complete the description of our autarkic equilibrium.

Proposition 4 *When Assumption 1 holds, there always exists a unique competitive equilibrium under autarky and asymmetric information. It is characterized by the price system* (p^{AI}, w^{AI}, r^{AI}) *that solves (4), (13) and (16).*

First, observe that the autarky price of the manufactured good decreases with asymmetric information. Indeed asymmetric information reduces the size of inefficient intermediate sectors using capital as an input. More capital becomes available for the capital intensive final good which consequently becomes cheaper.

$$p^{AI} = \left(\frac{\bar{L}}{\bar{K}} \left(\frac{1}{(1-\alpha)(1-\beta)\left(1+\frac{\mu\lambda}{1+\mu}\right)} - 1 \right) \right)^{1-\beta} \leq p^{FI} \tag{17}$$

with equality only when $\zeta = 1$.

[18] Assumption 1 ensures that this relative price adjustment mechanism is strong enough to overcome the income effect due to the existence of (endogenous) information rents. If it were not the case, then the income effect associated to information rents would produce an increased equilibrium rental rate of capital which in turn would feed back into increased information rents. This multiplier effect would render impossible the existence of a competitive equilibrium.

A priori, it is hard to compare autarky input factor prices under complete and asymmetric information. On the one hand, the downward shift of the zero-profit locus (13) due to the deterioration of the productivity index suggests that the equilibrium rental rate of capital and wage are lower under asymmetric information. On the other hand, the downward shift of the autarky locus increases the equilibrium wage (see Figure 2 below). The total impact of asymmetric information on the rental rate of capital ends up being unambiguous. However, its impact on wages depends on the parameters as shown below.

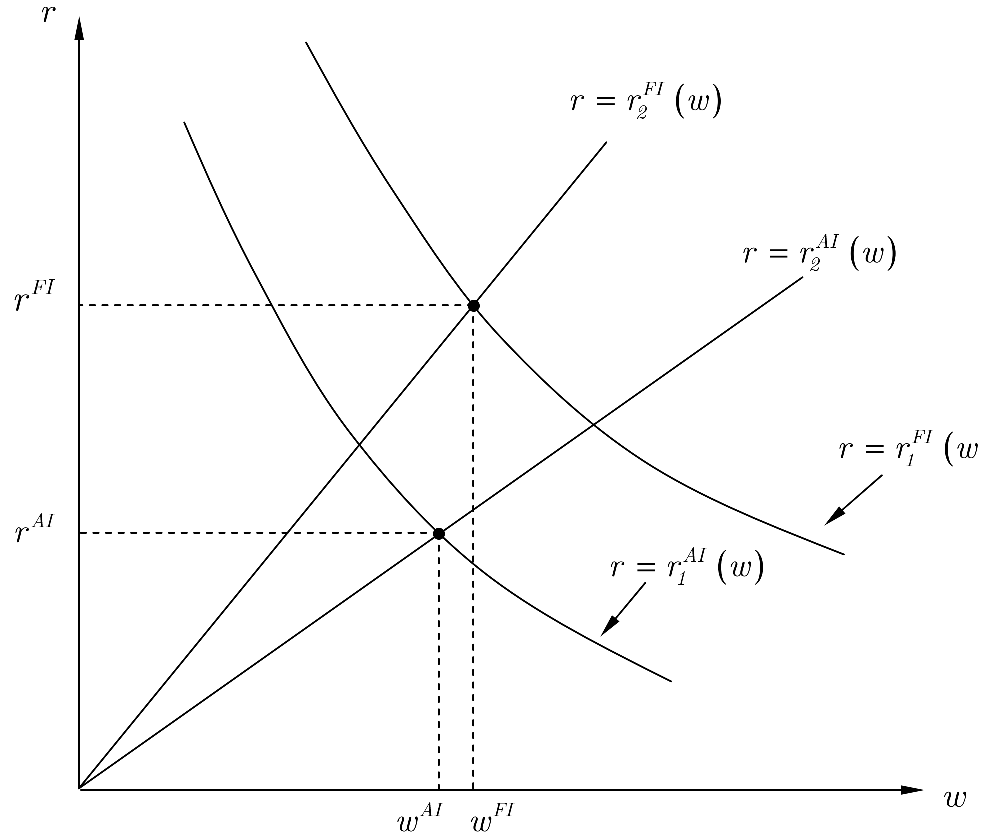

Figure 2: Equilibrium under autarky with and without asymmetric information.

Proposition 5 *Under asymmetric information, capital is always cheaper than under complete information, $r^{AI} < r^{FI}$. Wages are lower, i.e., $w^{AI} < w^{FI}$, if and only if*

$$\frac{\tilde{\Theta}_\zeta}{\Theta} > \frac{\left(1 + \frac{\mu\lambda}{1+\mu}\right)(1-(1-\alpha)(1-\beta))}{1 - \left(1 + \frac{\mu\lambda}{1+\mu}\right)(1-\alpha)(1-\beta)}. \tag{18}$$

Using Taylor expansions in the limiting case of small degrees of asymmetric information (i.e., $\Delta\theta$ small enough), it can be verified that condition (18) amounts to

Assumption 1. Changes in input prices are thus mostly explained by changes in the productivity index so that both r and w decreases with asymmetric information.

4.2 Free Trade

Under free trade, p is again fixed on the world market at an exogenous value. Following the same logic as under complete information, the pattern of trade can be immediately derived and depends on whether p is above or below p^{AI}.

Proposition 6 *Assume that $p^{FI} > p > p^{AI}$, then under complete information, the small economy contracts its production of the capital intensive good and expands that of the labor intensive one whereas it is the reverse under asymmetric information.*

Under those circumstances, asymmetric information changes the pattern of trade. To better understand this result, it is useful to come back on the definition of p^{AI} and rewrite

$$p^{AI} = \left(\widetilde{\left(\frac{\bar{L}}{\bar{K}}\right)}\left(\frac{1}{(1-\alpha)(1-\beta)} - 1\right)\right)^{1-\beta}$$

where

$$\widetilde{\left(\frac{\bar{L}}{\bar{K}}\right)} = \frac{\bar{L}}{\bar{K}}\left(\frac{\frac{1}{1+\frac{\mu\lambda}{1+\mu}} - (1-\alpha)(1-\beta)}{1-(1-\alpha)(1-\beta)}\right) < \frac{\bar{L}}{\bar{K}}.$$

That expression highlights that, under asymmetric information, the relative factor endowment $\frac{\bar{L}}{\bar{K}}$ of the economy has to be replaced by its *virtual* value $\widetilde{\left(\frac{\bar{L}}{\bar{K}}\right)}$ which is lower. With asymmetric information, everything happens thus as if the small country was relatively richer in the factor which is more intensively used by sectors affected by agency problems. Indeed, since these sectors contract their activity, capital is relatively cheaper and the small country specializes more easily in the capital intensive good. Asymmetric information induces a specialization bias.[19]

5 Normative Analysis

The standard normative conclusions of Trade Theory change under asymmetric information. One should not always expect free trade to be necessarily welfare-improving even for a small open economy that has optimally designed its domestic regulation.

[19] In our model, capital is the only factor affected by asymmetric information issues. More generally, what matters for trade patterns is the relative factor endowment of the economy, adjusted for the *factor content* of information rents.

Define first now the representative consumer's indirect utility function $V^{AI}(p)$ in the open economy under asymmetric information as follows:

$$(\mathcal{P}^{AI}): \quad V^{AI}(p) \equiv \max_{\{C_M, C_A, X_M, X_A, K, x_m(\cdot), x_a(\cdot)\}} \alpha ln C_M + (1-\alpha) ln C_A$$

subject to (6), (7), (8) and

$$K + \underset{\theta}{E}\left(\tilde{\theta}_\zeta(x_M(\theta) + x_A(\theta))\right) = (1-\zeta)\nu\Delta\theta(x_M(\bar{\theta}, p) + x_A(\bar{\theta}, p)) + \bar{K} \tag{19}$$

where $x_M(\bar{\theta}, p)$ and $x_A(\bar{\theta}, p)$ solve the maximization problem above.

The following proposition holds.

Proposition 7 *Under asymmetric information, $V^{AI}(p)$ is the representative consumer's utility function when the world price of manufactured good is p. In other words, the allocation of resources that solves $(\mathcal{P}^{AI})$ is the market equilibrium under asymmetric information in the open economy.*

Proposition 7 characterizes a *constrained* First Welfare Theorem under asymmetric information. It shows that the equilibrium allocation is in fact the solution to a centralized problem $(\mathcal{P}^{AI})$ provided that the resource constraint for the informationally sensitive input (19), here capital, is carefully modified. That modification encapsulates implicitly the constraints that asymmetric information imposes in redistributing wealth from the representative consumer viewed as an informed shareholder of the intermediate sector to the representative consumer viewed as an uninformed player.

As under complete information, the resource constraint (19) accounts for the capital endowment $\bar{K}$ but it differs from (9) on both sides. First, the new extra term $(1-\zeta)\nu\Delta\theta(x_M(\bar{\theta}, p) + x_A(\bar{\theta}, p))$ has been added on the resource side. Second, the efficiency parameter $\bar{\theta}$ has been replaced by its virtual value $\tilde{\bar{\theta}}_\zeta$ on the left-hand side. The intuition for these modifications is straightforward. Under asymmetric information, virtual efficiency parameters are the right concept to evaluate the marginal opportunity cost of using resources. Hence, any centralized maximization problem that aims at replicating the behavior of competitive markets for input factors that are regulated by a regulator having the objective function as in (1) with some redistributive concerns characterized by the parameter ζ must take into account those virtual efficiency parameters. Going from efficiency parameters to their virtual counterparts amounts to an implicit tax $(1-\zeta)\frac{\nu}{1-\nu}\Delta\theta$ (counted here in units of capital) on the use of capital by inefficient firms of the intermediate sectors. In a general equilibrium environment, the proceeds of that tax have to be included on the resource side which explains the newly added term $(1-\zeta)\nu\Delta\theta(x_M(\bar{\theta}, p)+x_A(\bar{\theta}, p))$ on the left-hand side of (19). Finally, $x_M(\bar{\theta}, p)$

and $x_A(\bar{\theta}, p)$ are obtained as fixed-points out of the optimization problem $(\mathcal{P}^{AI})$.[20]

Let us again denote by $\gamma(p)$ the non-negative multiplier of the trade-balance condition (6) and by $\gamma(p)r(p)$ the non-negative multiplier of the feasibility condition (19) at world price p for the manufactured good. The Envelope Theorem gives us:

$$\dot{V}^{AI}(p) = \gamma(p)\left(\left[X_M^{\beta}(p)K^{1-\beta}(p) - C_M(p)\right] + r(p)\nu(1-\zeta)\Delta\theta\left(\frac{\partial x_M}{\partial p}(\bar{\theta}, p) + \frac{\partial x_A}{\partial p}(\bar{\theta}, p)\right)\right).$$

At the autarky price p^{AI}, only the first bracketed term is zero since domestic production is equal to domestic consumption of that manufactured good. Intuitively, moving away from the autarky price by a small amount has now a first-order effect on welfare since it changes information rents in the intermediate sectors.

Slightly increasing p above p^{AI} boosts the domestic production of good M. This raises the demand for capital and increases its rental rate, decreasing in turn production of inefficient firms in the intermediate sectors. Starting from the autarky price, trade openness increases exports but also reduces information rents and welfare.

Using the specific Cobb-Douglas preferences, we can go further and easily compute

$$V^{AI}(p) = \alpha ln\alpha + (1-\alpha)ln(1-\alpha) - ln\gamma(p) - \alpha lnp$$

where now

$$\frac{1}{\gamma(p)} = R^{AI}(p) = \beta^{\beta}(1-\beta)^{1-\beta}\tilde{\Theta}_{\zeta}^{-\beta}\left(1 + \frac{\mu\lambda}{1+\mu}\right)\left(p\bar{K} + p^{-\frac{\beta}{1-\beta}}\bar{L}\right).$$

$V^{AI}(\cdot)$ is again U-shaped and minimized, as $V^{FI}(\cdot)$, for p^{FI} which is greater than p^{AI}. Hence, $\dot{V}^{AI}(p^{AI}) < 0$. The following proposition follows immediately.

Proposition 8 *Under asymmetric information, free trade is welfare-decreasing when $p^{AI} < p < p^{FI}$ whereas it is welfare-increasing when $p < p^{AI} < p^{FI}$.*

The intuition for this proposition is straightforward. Remember that optimal regulation contracts output in intermediate sectors. If opening borders induces a specialization which reinforces this domestic distortion, the additional distortionary effect offsets any gains from trade. A free trade regime is eventually Pareto inferior to autarky.

When $p > p^{AI}$, the domestic economy has a comparative advantage in the capital intensive tradable good. Free trade induces specialization in that sector. By increasing the demand for capital, free trade increases the rental rate of capital and reduces output

[20]This problem is self-generating in the sense that one of its constraints depends on the solution itself. See Martimort and Stole (2010) for other optimization problems exhibiting such self-generating property.

in the intermediate good sectors. This specialization exacerbates the initial downward output distortion of the intermediate sectors due to asymmetric information. This additional social cost has to be evaluated against the traditional gains from trade in production and consumption of the Hecksher-Ohlin framework.

As long as $p^{AI} < p < p^{FI}$, the social cost induced by this distortive specialization outweighs the traditional gains from trade and a free trade regime is always dominated by autarky. When $p^{FI} < p$, the gains from trade may be large enough that one may reestablish the superiority of openness above autarky. Indeed, it can be shown that there exists a threshold $\widetilde{p} > p^{FI}$ such that for $p^{FI} < p < \widetilde{p}$, autarky dominates free trade and, conversely for $p > \widetilde{p}$ free trade dominates autarky.

When $p < p^{AI}$, the economy has a comparative advantage in the labor intensive agricultural good. Free trade induces a specialization in that sector and a reduction of production of the capital intensive tradable good. This, in turn, expands intermediate sectors. This expansion mitigates the initial downward output distortion due to asymmetric information. Opening borders improves the allocation of resources in the economy and increases welfare. In that case, free trade generates two sources of social gains: the usual Hecksher-Ohlin gains from trade and the reduced domestic distortions associated with the existence of information rents. Free trade is better than autarky.

Proposition 8 shows how asymmetric information may dramatically change the standard positive and normative predictions of trade models. Under complete information, trade openness allows a better specialization of a small country and optimal regulation does not affect the pattern of trade. The increase in income of the export sector more than offset the loss incurred by the import sector. The utility of the representative consumer increases. All efficiency gains coming from a better specialization can be passed onto the representative customer. Of course, this requires that there is no constraint on redistributing wealth between owners of the tradable good who win from trade openness and owners of the sector who lose from it.

The key difference under asymmetric information comes from the existing endogenous dead-weight loss which makes such redistribution costly. Asymmetric information creates a wedge between price and marginal cost. Even though, *in fine*, the representative consumer pockets both the profits of final good sectors and the information rent of intermediate ones, the sum is less than under complete information.

6 Conclusion

Standard results from Trade Theory must be modified when asymmetric information makes it impossible to fully redistribute gains from trade within the domestic country. First, we showed that, for a small economy, free trade may no longer be welfare-improving even when accompanied by a set of optimally designed domestic regulations. Second, that small country's comparative advantages may be reversed compared to complete information.

The basic reason for this challenge of two of the most familiar insights from the Trade literature is simple: asymmetric information in intermediate sectors producing key inputs for tradeable goods introduces distortions that cannot be eliminated even when the largest set of policy instruments are available to regulate those sectors.

Trade openness improves welfare only when it mitigates distortions induced by optimal regulation under asymmetric information. It worsens welfare otherwise.

Because asymmetric information creates a wedge between prices and marginal costs in intermediate sectors, its impact on the gains from trade interestingly looks similar as what one would obtain in a case of complete information but without any regulation of the intermediate sectors. With unregulated intermediate sectors also, an increase in the price of the capital intensive good increases also the price of capital in the small economy. This in turn increases the dead-weight loss of monopoly pricing and may finally decrease welfare. It should be stressed however that, under complete information, there is no obstacle to implement corrective policies. Implicit in any such analysis of the distortions associated with monopoly pricing in intermediate sectors under complete information is the idea that the regulator faces exogenous constraints when choosing his instruments. Our framework with asymmetric information clearly endogenizes those constraints by giving them informational foundations and makes a similar point without ad hoc restrictions on the set of regulatory instruments that can be used. Bhagwati's well-known insight that well-designed policies could avoid distortion fails to take into account this dimension and only works for exogenous constraints.

On the normative side, it should also be clear that our results could be generalized to the case of partial trade liberalization. Depending on the starting point (positive trade with initial frictions due to transports costs or the imposition of an import tariff), further trade integration can be immiserizing.

Our model could also be extended by considering a more symmetric environment with two countries of similar size, each being affected by similar informational problems. Trade pattern depends then on the *virtual factor endowments* of those countries and, in particular, on the respective degrees of asymmetric information that their domestic regulations face. Generally, these factor endowments will have to account for the *factor content* of information rents that result from the respective degrees of asymmetric information that these economies face. Hence, even though countries may look quite similar in their factor endowments, differences in information structures may already be a source of trade. Following the lessons of our model, one expects countries whose regulated sectors are using more of a given input factor and which face the most significant information problem on these factors to export final goods using less of it. The intuition built for a small economy already suggests two aspects for the pattern of trade. First, optimal domestic regulations may affect resources allocation in the foreign country through the induced terms of trade effects. This opens scope for a strategic design of those regulatory policies. Second, free trade may not always be welfare-improving from the worldwide viewpoint.

By assuming monopolies in the intermediate sectors, we have made stronger the inefficiency due to asymmetric information. Two possible modifications of our basic model could make asymmetric information less of a concern and trade openness more attractive even though the main results of our analysis would carry over.

The first one would consist in introducing more competition in the intermediate sectors. Consider thus several firms competing for the right to serve any intermediate market. This more competitive environment can easily be modeled as an auction between privately informed competing firms having possibly independently distributed efficiency parameters. Assuming enough symmetry among competing firms, the optimal regulation would consist in first selecting the most efficient firm in each sector and then offering to that winning firm a regulatory contract close to that used in the monopoly case.[21] The major difference with our set-up comes from the fact that incentives for looking less efficient are somewhat reduced by the threat of losing the market even though these incentives remain present to a large extent. This reduces both inefficiency due to asymmetric information and the information rent that owners of the intermediate sectors grasp. Both effects go in the direction of making the asymmetric information model closer to the complete information environment but this does not change our major conclusions even though it affects their magnitudes.

Another modification of our set-up worth to tackle would consist in giving to regulators a more active role in bridging the informational gap between the industry and the final sector. Regulators may gather informative signals on the intermediate sectors. If regulators use this knowledge to defend the interests of final sectors, distortions and information rents in the intermediate sectors will be lower and although the re-

[21] Laffont and Tirole (1993, Chapter 7) and Riordan and Sappington (1987) among other studied such auctions for monopoly franchises under asymmetric information.

sults of the model would again come closer to the complete information environment, we would still keep the same kind of conclusions as obtained so far. Of course, this access to privileged information opens also the door to influence activities and regulatory capture by the intermediate sectors.[22] Such political exonomcy extensions may be worth exploring in our general equilibrium environment.

One could also depart from our representative consumer assumption to introduce some heterogeneity among factor owners. This would pave the way for a political economy analysis of trade and regulatory policies in a setting where asymmetric information is the source of the stakes that various interest groups may have to resist or to favor free trade.

Finally, our work emphasizes the importance of taking seriously the role of information rents in general equilibrium and how their distribution across economic agents affect the allocation of resources in a given economy. An interesting question obviously would be to assess how important this issue is from an empirical viewpoint. Casual observation suggests that service sectors producing differentiated and customized products are more subject to informational asymmetries than manufacturing sectors producing essentially standardized products. This would imply that information rents would play an increasing role in our post-industrialized societies where services represent a dominant share of the created value-added. Investigating the quantitative implications of this dimension for international trade and macroeconomics remains therefore an interesting challenge for future research.

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Appendix

Proof of Proposition 1. The optimal regulation is such that all participation constraints (2) are binding because rents of intermediate sectors are viewed as costly by the regulator.

• Consider first the A sector. Inserting the values so obtained of these rents into the maximand and optimizing respectively w.r.t. $x_A(\theta)$ and L yields the following first-order conditions:

$$\beta X_A^{\beta-\frac{\sigma-1}{\sigma}} L^{1-\beta} x_M^{-\frac{1}{\sigma}}(\theta) = r\theta, \tag{A1}$$

and

$$(1-\beta)X_A^{\beta} L^{-\beta} = w \tag{A2}$$

where $X_j^{\frac{\sigma-1}{\sigma}} = \underset{\theta}{E}\left(x_j(\theta)^{\frac{\sigma-1}{\sigma}}\right)$ for $j = M, A$.

From (A1), we deduce

$$x_A(\theta) = \left(\frac{\beta}{r\theta}\right)^{\sigma} L^{(1-\beta)\sigma} X_A^{\beta\sigma-\sigma+1}. \tag{A3}$$

Taking expectations, we get

$$X_A = \left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}} \left(\underset{\theta}{E}(\theta^{1-\sigma})\right)^{\frac{1}{(\sigma-1)(1-\beta)}} L. \tag{A4}$$

Using (A2), we also derive (3) from the zero-profit condition in the agricultural sector:

$$1 = \left(\frac{(1-\beta)}{w}\right)^{1-\beta} \left(\frac{\beta}{r}\right)^{\beta} \left(\underset{\theta}{E}(\theta^{1-\sigma})\right)^{\frac{\beta}{\sigma-1}}.$$

• Consider now the M sector. Optimizing respectively w.r.t. $x_M(\theta)$ and K yields:

$$x_M(\theta) = \left(\frac{\beta p}{r\theta}\right)^{\sigma} K^{(1-\beta)\sigma} X_M^{\beta\sigma-\sigma+1}, \tag{A5}$$

where

$$X_M = \left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}} \left(\underset{\theta}{E}(\theta^{1-\sigma})\right)^{\frac{1}{(\sigma-1)(1-\beta)}} K. \tag{A6}$$

Finally, we have:

$$1=\left(\frac{(1-\beta)p}{r}\right)^{1-\beta}\left(\frac{\beta p}{r}\right)^{\beta}\left(\underset{\theta}{E}(\theta^{1-\sigma})\right)^{\frac{\beta}{\sigma-1}}. \tag{A7}$$

This yields (4).

• Using (A3) and (A4) on the one hand and (A5) and (A6) on the other hand yields the following expressions of the levels of intermediate goods used in the final sectors:

$$x_M^{FI}(\theta)=\theta^{-\sigma}\Theta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}K\left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}} \text{ and } x_A^{FI}(\theta)=\theta^{-\sigma}\Theta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}L\left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}}. \tag{A8}$$

■

Proof of Proposition 2. Existence and uniqueness follow immediately since $r_1(\cdot)$ is decreasing with $r_1(0)=+\infty$, $r_1(+\infty)=0$ and $r_2(\cdot)$ is increasing over $[0,\infty[$ with $r_2(0)=0$ and $r_2(+\infty)=+\infty$. For the sake of completeness, we compute the equilibrium values of prices as follows:

$$r^{FI}=(1-\beta)^{1-\beta}\beta^{\beta}\Theta^{-\beta}p^{FI}, \quad w^{FI}=(1-\beta)^{1-\beta}\beta^{\beta}\Theta^{-\beta}\left(p^{FI}\right)^{-\frac{\beta}{1-\beta}} \tag{A9}$$

where p^{FI} is given by (10). ■

Proof of Proposition 3. The proof is identical to that of Proposition 1 except that θ is replaced by $\tilde{\theta}_\zeta$ and Θ is replaced by $\tilde{\Theta}_\zeta$ everywhere. In particular, we have

$$X_A^{AI}=\left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}}\tilde{\Theta}_\zeta^{\frac{1}{1-\beta}}L \text{ and } X_M^{AI}=\left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}}\tilde{\Theta}_\zeta^{\frac{1}{1-\beta}}K. \tag{A10}$$

where $X_j^{AI}=\left(\underset{\theta}{E}\left(x_j(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\sigma}{\sigma-1}}$ for $j=M,A$.

For further references, the productions of intermediate goods in both sectors are respectively given by:

$$x_M^{AI}(\theta)=\tilde{\theta}_\zeta^{-\sigma}\tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}K\left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}} \text{ and } x_A^{AI}(\theta)\tilde{\theta}_\zeta^{-\sigma}\tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}L\left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}}. \tag{A11}$$

■

Consumer's income under asymmetric information (equation (15)). Inserting the values of $x_M^{AI}(\theta)$ and $x_A^{AI}(\theta)$ obtained from (6) into (14) yields the following expression for the representative consumer's income under asymmetric information

$$R^{AI}=w\bar{L}+r\bar{K}+r\nu\Delta\theta\tilde{\bar{\theta}}_\zeta^{-\sigma}\tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}\left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}}\left(\bar{L}+p^{\frac{1}{1-\beta}}K\right) \tag{A12}$$

where the amount of capital K used in the final sector satisfies

$$K=\bar{K}-\underset{\theta}{E}\left(\theta(x_M^{AI}(\theta)+x_A^{AI}(\theta))\right). \tag{A13}$$

Taking into account (A11) yields:

$$\underset{\theta}{E}(\theta x_M^{AI}(\theta)) = \left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}} K\tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}} \left(\nu\underline{\theta}^{1-\sigma} + (1-\nu)\bar{\theta}\tilde{\bar{\theta}}_\zeta^{-\sigma}\right)$$

and

$$\underset{\theta}{E}(\theta x_A^{AI}(\theta)) = \left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}} \bar{L}\tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}} \left(\nu\underline{\theta}^{1-\sigma} + (1-\nu)\bar{\theta}\tilde{\bar{\theta}}_\zeta^{-\sigma}\right).$$

Therefore, (A13) becomes

$$K = \bar{K} - \left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}} \tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}} \left(\nu\underline{\theta}^{1-\sigma} + (1-\nu)\bar{\theta}\tilde{\bar{\theta}}_\zeta^{-\sigma}\right)\left(\bar{L} + p^{\frac{1}{1-\beta}}K\right).$$

So that we get

$$\bar{L} + p^{\frac{1}{1-\beta}}K = \frac{\bar{L} + p^{\frac{1}{1-\beta}}\bar{K}}{1 + \left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}} \tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}} \left(\nu\underline{\theta}^{1-\sigma} + (1-\nu)\bar{\theta}\tilde{\bar{\theta}}_\zeta^{-\sigma}\right)}.$$

Inserting into (A12) yields

$$R^{AI} = w\bar{L} + r\bar{K} + \frac{r\nu\Delta\theta\tilde{\bar{\theta}}_\zeta^{-\sigma}\tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}} \left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}}\left(\bar{L} + p^{\frac{1}{1-\beta}}\bar{K}\right)}{1 + \left(\frac{\beta p}{r}\right)^{\frac{1}{1-\beta}} \tilde{\Theta}_\zeta^{\frac{-1+\sigma-\beta\sigma}{1-\beta}} \left(\nu\underline{\theta}^{1-\sigma} + (1-\nu)\bar{\theta}\tilde{\bar{\theta}}_\zeta^{-\sigma}\right)}. \tag{A14}$$

Using (4) and (13) yields $p^{\frac{1}{1-\beta}} = \frac{r}{w}$ and $r^{\frac{\beta}{1-\beta}}w = \beta^{\frac{\beta}{1-\beta}}(1-\beta)\tilde{\Theta}_\zeta^{-\frac{\beta}{1-\beta}}$. Inserting into (A14) and simplifying using the definitions of λ and μ proposed in the text yields (15). ■

Proof of Proposition 4. The proof is similar to that of Proposition 2. We have:

$$r^{AI} = (1-\beta)^{1-\beta}\beta^\beta\tilde{\Theta}_\zeta^{-\beta}p^{AI}, \quad w^{AI} = (1-\beta)^{1-\beta}\beta^\beta\tilde{\Theta}_\zeta^{-\beta}\left(p^{AI}\right)^{-\frac{\beta}{1-\beta}} \tag{A15}$$

where p^{AI} is given by (17). ■

Proof of Proposition 5. Condition (18) follows from comparing (A9) and (A15). ■

Proof of Proposition 6. Immediate. ■

Proof of Proposition 7. The proof consists in identifying the solution to $(\mathcal{P}^{AI})$ to the competitive equilibrium. Denote thus by γ, $\mu\gamma$, $\eta\gamma$, and $r\gamma$ the respective multipliers of (6), (7), (8) and (19) where the dependency of these multipliers on p is left implicit. The Lagrangean for $(\mathcal{P}^{AI})$ can be written as:

$$L(C_M, C_A, X_M, X_A, K, x_M(\cdot), x_A(\cdot)) = \alpha lnC_M + (1-\alpha)lnC_A$$

$$+\gamma(pX_M^\beta K^{1-\beta} + X_A^\beta\bar{L}^{1-\beta} - pC_M - C_A)$$

$$+r\gamma\left(\bar{K}+(1-\zeta)\nu\Delta\theta(x_M(\bar{\theta},p)+x_A(\bar{\theta},p))-K-\underset{\theta}{E}\left(\tilde{\theta}_\zeta(x_M(\theta)+x_A(\theta))\right)\right)$$

$$+\mu\gamma\left(\left(\underset{\theta}{E}\left(x_M(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\sigma}{\sigma-1}}-X_M\right)+\eta\gamma\left(\left(\underset{\theta}{E}\left(x_A(\theta)^{\frac{\sigma-1}{\sigma}}\right)\right)^{\frac{\sigma}{\sigma-1}}-X_A\right).$$

The optimality conditions for $(\mathcal{P}^{AI})$ give us the following set of first-order conditions:

$$\frac{\alpha}{C_M(p)}=p\gamma,\quad \frac{1-\alpha}{C_A(p)}=\gamma; \tag{A16}$$

$$p\beta X_M^{\beta-1}(p)K^{1-\beta}(p)=\mu,\quad p(1-\beta)X_M^{\beta}(p)K^{-\beta}(p)=r; \tag{A17}$$

$$\beta X_A^{\beta-1}(p)\bar{L}^{1-\beta}(p)=\eta; \tag{A18}$$

$$\mu x_M(\theta,p)^{-\frac{1}{\sigma}}X_M^{\frac{1}{\sigma}}(p)=\eta x_A(\theta,p)^{-\frac{1}{\sigma}}X_A^{\frac{1}{\sigma}}(p)=r\tilde{\theta}_\zeta. \tag{A19}$$

Those conditions can be readily identified with behavior on the competitive market.

• **Supply side.** From (A19) and taking expectations, we get

$$\mu=\eta=r\tilde{\Theta}_\zeta. \tag{A20}$$

Inserting the conditions (A20) into the first equation in (A17) and also in (A18) yields the same expressions for $X_M(p)$ and $X_A(p)$ as in (A10) with $L=\bar{L}$ when the labor market is at equilibrium.

Inserting those latter values of $X_M(p)$ and $X_A(p)$ into (A19) yields the same expressions for $x_M(\theta,p)$ and $x_A(\theta,p)$ as in (A11) with $L=\bar{L}$ when the labor market is at equilibrium.

Using the expression of μ coming from (A20) into (A17) yields

$$r=(1-\beta)^{1-\beta}\beta^{\beta}\tilde{\Theta}_\zeta^{-\beta}p. \tag{A21}$$

• **Demand side.** From (A16), we get

$$1=\gamma(pC_M(p)+C_A(p))=\gamma\left(pX_M^{\beta}(p)K^{1-\beta}(p)+X_A^{\beta}(p)\bar{L}^{1-\beta}\right) \tag{A22}$$

where the second equality follows from the slackness condition for (6). Therefore, $\gamma>0$.

Denote

$$R^{AI}=pX_M^{\beta}(p)K^{1-\beta}(p)+X_A^{\beta}(p)\bar{L}^{1-\beta} \tag{A23}$$

and

$$w=(1-\beta)^{1-\beta}\beta^{\beta}\tilde{\Theta}_\zeta^{-\beta}p^{-\frac{\beta}{1-\beta}}. \tag{A24}$$

With those notations in hands, (A16) becomes

$$C_M(p) = \frac{\alpha R^{AI}}{p}, \quad C_A(p) = (1-\alpha)R^{AI}. \tag{A25}$$

The slackness condition for (19) (taking into account that $\gamma > 0$) and (A24) altogether imply that one can write

$$\begin{aligned} R^{AI} = & \left[pX_M^{\beta}(p)K^{1-\beta}(p) - rK(p) - r\underset{\theta}{E}\left(\tilde{\theta}_{\zeta}x_M(\theta,p)\right)\right] \\ & + \left[X_A^{\beta}(p)\bar{L}^{1-\beta} - w\bar{L} - r\underset{\theta}{E}\left(\tilde{\theta}_{\zeta}x_A(\theta,p)\right)\right] \\ & + r\left(\bar{K} + \nu\Delta\theta(x_M(\theta,p) + x_A(\theta,p))\right) + w\bar{L}. \end{aligned}$$

Because of constant returns to scale in the final sectors, the two bracketed terms above are zero which yields

$$R^{AI} = r\left(\bar{K} + \nu\Delta\theta(x_M(\theta,p) + x_A(\theta,p))\right) + w\bar{L}. \tag{A26}$$

Inserting into (A25) gives the expression of demand for tradable goods exactly as in the competitive equilibrium. ■

Proof of Proposition 8. The proof is straightforward given what is in the main text. For completeness, we nevertheless check that $x_M(\bar{\theta},p) + x_A(\bar{\theta},p)$ decreases with p so that $\dot{V}^{AI}(p^{AI}) < 0$. Tedious computations give us:

$$x_M(\bar{\theta},p) + x_A(\bar{\theta},p) = \tilde{\bar{\theta}}_{\zeta}^{-\sigma}\tilde{\Theta}_{\zeta}^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}\left(\frac{\beta}{r}\right)^{\frac{1}{1-\beta}}\left(\bar{L} + p^{\frac{1}{1-\beta}}K\right)$$

$$= \frac{\tilde{\bar{\theta}}^{-\sigma}\tilde{\Theta}_{\zeta}^{\frac{-1+\sigma-\beta\sigma}{1-\beta}}}{1 + \left(\frac{\beta}{1-\beta}\right)^{\frac{1}{1-\beta}}\tilde{\Theta}_{\zeta}^{-1+\sigma}\left(\nu\underline{\theta}^{1-\sigma} + (1-\nu)\bar{\theta}\tilde{\bar{\theta}}_{\zeta}^{-\sigma}\right)}\left(p^{-\frac{1}{1-\beta}}\bar{L} + \bar{K}\right).$$

■