Local Learning, Trade Policy and Industrial Structure Dynamics*

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September 5, 2005

Abstract

In a small open economy with heterogeneous firms, in which tariffs determine the mass of active firms, free trade optimality depends positively on the level of firm heterogeneity and negatively on transportation costs. The benefits from temporary protection depend on the level of backwardness: for a given mass of backward firms, the relative gains from protection increase with their quality and decrease with the quality of advanced firms; for given production quality levels, the relative advantage of protection increases with the mass of backward firms.

JEL-Classification: D51, D62, F12, F13

Key-words: Production network, Learning externalities, Infant industry

1 Introduction

How and when should an industrial structure be protected? Answers to this question go back into to the early stages of development of contemporary industrialized countries and have motivated a plethora of work in

*We would like to thank Robert Boyer, Antonio Cabrales, Hector Calvo, Antonio Ciccone, Gregory Corcos, Jayasri Dutta, Robert Elliot, Gino Gancia, Philippe Martin and Jaume Ventura for very useful discussions, and participants to seminars at Paris-Jourdan School of Economics, Universidad de Buenos Aires, University of Birmingham and UPF for helpful comments, with the usual caveat.

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international trade and vigorous disagreements among economists and policy makers. Consensus in this area has been alternating over time between the polar cases of infant industry protection and trade liberalization. We argue that the welfare effects of these two policies crucially depend, among other things, on an economy's initial industrial structure and on the characteristics of its development process.

We focus on a developing country, modelled as a small open economy, and we emphasize the role of localized learning externalities. We thus consider a dynamic version of the infant industry argument, in which development of a strong local industrial network may be crucial for overall development, but may require a temporary phase of protection. The dynamic costs and benefits of such protection, relative to free trade, depend upon domestic firms' initial distance from the technological frontier and upon the mass of domestic firms which are relatively far away from the frontier[1]. Along these two aspects we define an industrial structure.

Industrial strategies in developing countries are often based on imitation and replication of advanced economies[2]. This has long been recognized, for instance by Hirschman (1968) and by Amsden (1989), who observes: "If industrialization first occurred in England on the basis of invention, and if it occurred in Germany and the United States on the basis of innovation, then it occurs now among 'backward' countries on the basis of learning" (Amsden 1989:4)[3]. That is why we focus on a learning-based development process[4].

When development comes through learning and replication, there tends to be a strong form of international competition, because 'backward' countries tend to produce very close substitutes to the goods produced in 'advanced' economies, although at a different quality level. Because of such competition, trade openness forces out of the market those firms, which are

[1] It is worth mentioning that Aghion, Burgess, Redding and Zilibotti (2005) show how a firm's reaction to an increase of import competition dramatically depends on productivity differences between domestic and the world technological frontier.

[2] This connects our analysis to the debate on the import substitution model as a strategy for initial development. In that debate the implied idea for most developing countries was to replicate the goods imported from the North (Lewis 1954). Indeed, this seems to be what several of them did, even those which successfully managed to give their economies an outward orientation (see Bruton 1998, for an assessment of import substitution model).

[3] 'Backward' countries were at the time South-Eastern Asian countries (especially Korea).

[4] To focus on this aspect, we disregard intentional efforts to create or adopt new knowledge. Intentional learning or innovation efforts are obviously important, but they are also quite well studied. Among the many contributions in that area, our model bares most resemblance with Segestrom (1998).

neither competitive in quality nor in costs. While this may be a source of efficiency gains from trade, we discuss conditions, under which it may have adverse dynamic consequences.

A recent literature, which we discuss below, documents that interactions with other firms in the same local area are a relevant source of a firm's learning ability. Thus, a firm's development opportunities depend, among other things, on the industrial network surrounding it. Trade policy determines in equilibrium the mass of active firms and their size. This determines their interaction patterns and the aggregate learning externalities from which they can benefit, thus influencing the dynamic development of the initial industrial structure[5]. Such development, in turn, ultimately determines the dynamic costs and benefits of the policy adopted, which are therefore different for different initial industrial structures.

If free trade, by forcing several industries to close, leads to a relevant loss of learning externalities, static gains from trade may transform into dynamic failures of development. For which initial industrial structures this is more likely to happen, and what are the dynamic costs and benefits of different policies when applied to different countries, are the main questions addressed in this paper.

Our main findings are the following. Free trade tends to be better for more heterogeneous structures, for which the cost of protecting 'backward' industries would be high[6]. The lower transportation costs, the lower the degree of heterogeneity required for free trade to be better. Thus globalization makes free trade a better policy for a wider range of industrial structures.

In turn, when free trade forces several industries to close, the implied loss of learning externalities may prevent even relatively 'advanced' domestic industries from catching up with the technological frontier, whereas a policy of temporary protection would first render the domestic industrial structure more homogeneous and then allow it to converge to the frontier. Therefore initial protection of 'backward' industries tends to be better than free trade when such industries constitute a relevant part of the economy and when their distance from the technological frontier is not too high.

[5]Learning externalities to a firm depend both on the number of other linked firms in the local industrial network and on how much it can learn from each link. This in turn is likely to depend both on the technological level of linked firms and on their frequency of interaction, which may be proxied by their size.

[6]Heterogeneity is here conceived in terms of the quality gap between the group of technologically most backward domestic firms and the group of most advanced ones. In the remainder of the paper we indifferently refer to these two groups of firms as 'backward' and 'advanced', 'low quality' and 'high quality', or 'bad' and 'good', respectively.

More broadly, the relative gains to initial protection increase with the quality of backward firms (the cost of protection becomes lower), decrease with the quality of advanced firms (a lower level of heterogeneity reduces the benefits from free trade) and increase with the mass of backward firms (the loss of learning externalities would be higher). In essence, a rather homogeneous industrial structure, with all firms at a similar (and not too wide) quality gap from the frontier, is more worth protecting than a heterogeneous industrial structure, with a few very backward sectors and many relatively advanced ones.

We also discuss how farsighted a policy maker should be to choose the right policy, and observe that this also changes with the initial industrial structure. Thus some countries are more exposed to policy mistakes than others, due to a stronger temptation to follow a policy that is better in the short run, but worse in the long run.

The remainder of this paper is articulated as follows. Section 2 puts our work in perspective with respect to the related literature on the learning-based infant industry argument. Sections 3 and 4 introduce the model and discuss its static equilibria. Sections 5 introduces the leaning dynamic and presents simulation results. Section 6 concludes.

2 Learning and infant industry in perspective

Reasons for or against protection of backward industries are various. On one hand, it has been argued that if industrial firms exhibit convexities in their learning processes, protection against import competition might be a valid ingredient of any development strategy. According to this learning-based infant industry argument, and conditional on various assumptions, 'infant' or 'backward' industries should be protected for the time they need to catch-up with the technological cutting edge[7].

On the other hand, the use of some degree of protectionism has been increasingly challenged. First, protection may be welfare-reducing because it may either make imports more expensive or lead to their substitution by lower quality, domestically produced goods (Johnson, 1965). Second, as protection implies lower competition, it might reduce incentives to improve performance and an infant industry or firm may remain indefinitely in an

[7] The infant industry argument was initially developed by Alexander Hamilton 1791 and Friedrich List 1885. It has also been argued that active policies can switch the comparative advantage (see e.g. Krugman 1987 and Redding 1999) and overcome specialization traps, as in Grossman and Helpman (1990) or, based on a different set of assumptions, as in the seminal works of Prebisch (1950) and Singer (1950).

immature state of evolution (see for instance Meade 1955 and Baldwin 1969). Third, from a political economy perspective, it has also been emphasized that, though infant, some industries may be sufficiently organized so as to endogenously determine a suboptimal level of protection (Grossman and Helpman 1994 and Feenstra 2003).

What is sure is that the potential net benefits or costs of protection must be explicitly stated for this to be a recommendable policy. As it has been pointed out by Lucas (1984),

> "..in the end, only a careful weighing of intertemporal, social costs and benefits can discern whether infant industry protection might be justified."

In confluence with such a claim, the dynamic effects of different forms of active trade policy (import tariff, quotas or subsidies), have been investigated by the economics literature over the last three decades. In his pioneer work, Bardham (1971) assumes learning by doing at a single industry level, while Melitz (2005) discusses the kind of instrument to be used when protection is an optimal policy. Multi-industry models have been also developed. Clemout and Wan (1970) analyze industries with different learning functions. Succar (1987), and Young (1991) allow for learning across sectors. As an exception, Melitz's paper explicitly carries out a dynamic cost-benefit analysis of protecting an infant industry, the so-called Mill-Bastable test, and shows how results are conditional on the firms learning function.

A lesson from this literature, independently on how explicit it might be, is that the characteristics of the learning process are a key dimension to be analyzed when assessing the net benefits or costs of any trade policy. We return to this question in our dynamic analysis.

3 The model

We consider a small open economy, populated by a measure 1 of identical individuals, each endowed with 1 unit of labor, which is supplied inelastically in a competitive labor market, and where a continuum $[0, 1]$ of goods are produced. Good 1 is a consumption good, produced and sold by a perfectly competitive representative firm; goods $[0, 1)$ are intermediate goods, produced and sold by monopolistic firms.

The representative consumer maximizes

$$U = \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t \ln c(t), \tag{1}$$

where $\rho \in (0,1)$ is the intertemporal discount rate and $c(t)$ is consumption at time t. Since we do not consider any asset, the solution to this problem reduces to the solution of the static problem, so that demand for good 1 (the consumption good) at time t is

$$y^d(1,t) = \frac{E(t)}{p(1,t)}, \tag{2}$$

where $E(t)$ denotes aggregate income and $p(1,t)$ the price of good 1, both at time t. Aggregate income

$$E(t) = W(t) + \Pi(t) + T(t) \tag{3}$$

is equal to the sum of aggregate wage income $W(t)$, which under full employment simply equals the wage rate $w(t)$, aggregate profits $\Pi(t) = \int_0^1 \pi(m,t)\,\mathrm{d}m$, where $\pi(m,t)$ denotes firm m's profits at time t, and aggregate tariff revenue on imports $T(t)$, which will be specified below [8].

Each intermediate good $m \in [0,1)$ is produced with labor according to the decreasing returns to scale technology

$$y(m,t) = L(m,t)^{\alpha}, \tag{4}$$

with $\alpha \in (0,1)$[9].

Intermediate goods, which are both horizontally and vertically differentiated, are the only input in the production of the unique consumption good, which is produced according to the constant returns to scale technology

[8] The reason why we keep this specification so simple is that we are more interested in the production side rather than in the consumption side. Specifically, we focus on the dynamics of the industrial structure of our economy.

[9] Most of our qualitative results would still hold if we assumed a technology with initially increasing and eventually decreasing returns to scale. Analysis of increasing returns for any quantity would require a different model. In a small open economy model with perfect substitutability between domestic and foreign quality of a given variety of intermediates, and with a continuum of intermediates, increasing returns in their production would be incompatible with positive volumes of exports in equilibrium. The reason is that export volumes would be positive only if a positive mass of firms exports, but then each of these exporters would like to grow indefinitely larger, so that aggregate demand for labor would exceed demand, and wages would keep rising until exporting is not profitable (but, at most, for a zero measure of firms).

$$y(1,t) = \left[\int_0^1 h(m,t)^{\frac{\sigma-1}{\sigma}} \mathrm{d}m \right]^{\frac{\sigma}{\sigma-1}}, \tag{5}$$

where $\sigma > 1$ captures the elasticity of substitution between any two different varieties of intermediate goods and $h(m,t)$ is the 'effective input' of good m at time t[10].

The 'effective input', which may be either bought locally or imported from the rest of the world, is given by its quantity multiplied by its quality:

$$h(m,t) = \begin{cases} x(m,t)v(m,t) & , \text{ if it is bought locally} \\ x(m^*,t)v(m^*,t) & , \text{ if it is imported} \end{cases} \tag{6}$$

where $x(m,t)$ denotes local quantity and $v(m,t)$ local quality of the domestically produced good m, and m^* is a perfect substitute to m, produced in the rest of the world at the quality frontier $v(m^*,t)$.

Local intermediate goods have to directly compete with their foreign perfect substitutes. Taking into account the presence of an import tariff $\tau(t) \geq 0$ (applying to landed import and the same for each variety at a given time) and of transport (or adoption) costs of the iceberg type $a \geq 0$, which render the buyer price of an imported intermediate good equal to $p(m^*,t)[1+\tau(t)](1+a)$, the final good producer decides whether to buy locally or to import according to the best quality/price ratio[11]: the set of locally acquired inputs, and indeed of domestic intermediate good producers who are active at all, is $D(t) = \left\{ m \in [0,1) : \frac{v(m,t)}{p(m,t)} \geq \frac{v(m^*,t)}{p(m^*,t)[1+\tau(t)](1+a)} \right\}$, where $p(m,t)$ denotes the price of good m at time t set by its local producer. Therefore, defining the threshold function

$$p_H(m,t) \equiv \frac{v(m,t)}{v(m^*,t)} p(m^*,t)[1+\tau(t)](1+a), \tag{7}$$

we have $D(t) = \{m \in [0,1) : \ p(m,t) \leq p_H(m,t)\}$. Goods $m \in [0,1) \setminus D(t)$ are not produced domestically and their foreign perfect substitutes are are imported.

Calling $M(m^*,t)$ the quantity of good m^* imported at time t, this implies that the aggregate revenue from import tariff is

[10] Together with perfect competition, it is equivalent to assuming that each consumer assembles and consumes a bundle of traded intermediates.

[11] Any given variety of intermediate good at any point in time can be either acquired locally or imported, but not both. Further, whatever quantity of a given variety is produced domestically at any point in time, it is first absorbed by domestic demand, and then, if production exceeds local demand, exported.

$$T(t) = \int_{[0,1)\setminus D(t)} \tau(t) p(m^*, t)(1+a) M(m^*, t) \mathrm{d}m^*. \quad (8)$$

A similar production structure for the world economy implies that the final good producer in the rest of the world will be willing to import intermediate good m from our small economy only if the quality/price ratio is convenient. Letting $\tau^*(t)$ be the foreign import tariff at time t, the set of exportable intermediate goods for our small economy is

$$F(t) = \left\{ m \in [0,1) : \frac{v(m,t)}{p(m,t)[1+\tau^*(t)](1+a)} \geq \frac{v(m^*,t)}{p(m^*,t)} \right\}. \quad (9)$$

Defining the threshold function

$$p_L(m,t) \equiv \frac{v(m,t)}{v(m^*,t)} \frac{p(m^*,t)}{[1+\tau^*(t)](1+a)}, \quad (10)$$

we have $F(t) = \{m \in [0,1) : \; p(m,t) \leq p_L(m,t)\}$.

We assume the rest of the world immediately responds reciprocally to the tariff choice of the domestic economy, by imposing the same import tariff $(\tau^*(t) = \tau(t))$[12].

Equations (7) and (10) then show that a higher level of tariff protection allows a greater number of domestic intermediate good producers to survive, but at the same time reduces the number of them who may profitably export.

We now drop for notational simplicity the time index. The domestic producer of intermediate good $m \in [0,1)$ receives a local demand $x(m)$ and a foreign demand $x^*(m)$, so the total demand she receives is $y^d(m) = x(m) + x^*(m)$[13]. Letting P be the hedonic price aggregator defined below at equation (14), local demand is

[12] We regard this assumption as the most meaningful to study the dynamic effects of trade policy in the context of a small open economy model: keeping the tariff set by the rest of the world fixed would be dynamically implausible, but for a deeper analysis of the tariff choice problem of the rest of the world a different, more complicated, two country (or n country) model would be better suited than our small open economy model. Yet our interest is not on strategic trade policy, but rather on the interaction of different industrial structures and dynamic learning, and on its implications for policy. We feel that our assumption reaches a good compromise between plausibility and simplicity.

[13] When necessary, we will write $x\left(m \,|p_L(m)\right)$ to denote local demand of good m at price $p_L(m)$ (and analogously for other prices), but we drop the price for notational simplicity whenever this does not create confusion.

$$x(m) = \begin{cases} p(m)^{-\sigma} \left[v(m)P\right]^{\sigma-1} p(1)y(1) & , \quad \text{if } p(m) \leq p_H(m) \\ 0 & , \quad \text{if } p(m) > p_H(m) \end{cases} \tag{11}$$

At price $p(m) = p_L(m)$, local production of intermediate goods is assumed to be first absorbed by local demand and then exported for the exceeding part. Since we are dealing with a small open economy, foreign demand is infinitely elastic at $p_L(m)$:

$$x^*(m) = \begin{cases} \in \left[x\left(m \left| p_L(m)\right.\right), \infty\right) & , \quad \text{if } p(m) = p_L(m) \\ 0 & , \quad \text{if } p(m) > p_L(m) \end{cases} \tag{12}$$

When $p(m) > p_H(m)$, good m is not bought locally and its perfect substitute m^* is imported. Local demand for import is

$$M(m^*) = \begin{cases} \left[p(m^*)(1+a)(1+\tau)\right]^{-\sigma} \left[v(m^*)P\right]^{\sigma-1} p(1)y(1) & , \quad \text{if } p(m) > p_H(m) \\ 0 & , \quad \text{if } p(m) \leq p_H(m) \end{cases} \tag{13}$$

While equation (12) just follows from our assumptions, equations (11) and (13) are obtained from cost minimization given the technology described in (5) and (6).

The term P that appears in (11) and in (13) is a price index corresponding to the marginal cost of production of good 1 and is determined taking into account the fact that prices must be weighted by quality and that there is the possibility to import intermediate goods:

$$P = \left\{ \int_0^1 \left[\frac{p^F(m)}{v^F(m)}\right]^{1-\sigma} \mathrm{d}m \right\}^{\frac{1}{1-\sigma}}, \tag{14}$$

where

$$p^F(m) = \begin{cases} p(m) & , \quad \text{if } p(m) \leq p_H(m) \\ p(m^*)(1+\tau)(1+a) & , \quad \text{if } p(m) > p_H(m) \end{cases}$$

and

$$v^F(m) = \begin{cases} v(m) & , \quad \text{if } p(m) \leq p_H(m) \\ v(m^*) & , \quad \text{if } p(m) > p_H(m) \end{cases} .$$

Merging the previous equations yields total demand for good $m \in [0, 1)$:

$$y^d(m) = \begin{cases} \in [x(m\,|p_L(m)), \infty) & , \quad \text{if } p(m) = p_L(m) \\ x(m) & , \quad \text{if } p(m) \in (p_L(m), p_H(m)] \\ 0 & , \quad \text{if } p(m) > p_H(m) \end{cases} \tag{15}$$

Finally, recalling that D is the set of active domestic intermediate good producers, the overall demand for labor is

$$L^d = \int_D [y(m)^{\frac{1}{\alpha}}]\mathrm{d}m. \tag{16}$$

We can now solve the firms' profit maximization problem. The final good producer operates in a perfectly competitive market and thus sells its product at its marginal cost:

$$p(1) = P. \tag{17}$$

The case of intermediate good producers is somewhat more complicated. Recall that they are monopolists facing a discontinuous demand function. They first decide whether to produce or not and then, if they produce, they establish their optimal quantity of production under the constraints imposed by technology (equation 4) and demand (equation 15). Defining the two thresholds $y_H(m) \equiv x(m\,|p_L(m))$ and $y_L(m) \equiv x(m\,|p_H(m))$, using inverse demand and letting $R(y(m))$ be the revenues and $C(y(m))$ the cost, we can express profits as a function of quantity as $\pi(m) = R(y(m)) - C(y(m))$, where

$$R(y(m)) = \begin{cases} 0 & , \quad \text{if } y(m) < y_L(m) \\ y(m)^{\frac{\sigma-1}{\sigma}}[v(m)P]^{\frac{\sigma-1}{\sigma}}[p(1)y(1)]^{\frac{1}{\sigma}} & , \quad \text{if } y(m) \in [y_L(m), y_H(m)) \\ p_L(m)y(m) & , \quad \text{if } y(m) \geq y_H(m) \end{cases} \tag{18}$$

and, letting w be the wage rate,

$$C(y(m)) = wy(m)^{\frac{1}{\alpha}} \tag{19}$$

The profit function is twice differentiable almost everywhere, it is continuous but not differentiable at $y_H(m)$, it is discontinuous at $y_L(m)$, and it is twice differentiable and concave within each of the ranges determined by these two thresholds, but it is not globally concave. Therefore, the usual condition of the equality between the marginal cost (MC) and the marginal revenue (MR) is neither sufficient nor necessary to ensure optimality. This implies that the solution of intermediate good producers' profit maximization problem is analytically complicated and we go through all the analytical details in Appendix A. Here we show directly the result.

Lemma 1 ***(intermediate firms' optimal choice)*** *Consider a domestic intermediate firm's profit maximization problem. For either sufficiently low or high w there exists a unique (local and global) profit maximizing quantity; for intermediate wage levels there may exist two local optima, one involving production just for the domestic market and one also involving exports. In such case firm's choice is determined by comparison of the profitability of these two strategies.*

More explicitly, $\forall m \in [0,1)$, there exist positive thresholds $w_0(m)$, $\widehat{w_1}(m)$, $\widetilde{w_1}(m)$ and $\overline{\tau}$, such that

1. *If $w \leq \frac{\sigma-1}{\sigma}\widehat{w_1}(m)$, then m produces $y_E(m) = [\frac{\alpha}{w}p_L(m)]^{\frac{\alpha}{1-\alpha}}$.*

2. *If $w \in (\frac{\sigma-1}{\sigma}\widehat{w_1}(m), max\{\widehat{w_1}(m), \widetilde{w_1}(m)\})$, then m's choice depends on a combination of wage and protection level.*

    - *For $\tau \leq \overline{\tau}$, we have two cases:*
        - *if $w < \widetilde{w_1}(m)$, then m compares $\pi(y_E(m))$ and $\pi(y_M(m))$;*
        - *if $w \geq \widetilde{w_1}(m)$, then m compares $\pi(y_E(m))$ and $\pi(y_L(m))$.*
    - *For $\tau > \overline{\tau}$, we have again two cases:*
        - *if $w < \widehat{w_1}(m)$, then m compares $\pi(y_E(m))$ and $\pi(y_M(m))$;*
        - *if $w \geq \widehat{w_1}(m)$, then m produces $y_M(m)$.*

3. *If $w \in [max\{\widehat{w_1}(m), \widetilde{w_1}(m)\}, w_0(m)]$, then m produces $y_L(m)$.*

4. *If $w > w_0(m)$, then m stays inactive.*

Proof See Appendix A. ■

Given this result, it becomes clear that, in order to characterize some equilibria of the model, it may become necessary to first identify a candidate equilibrium and then check whether the optimality conditions established by Lemma 1 are satisfied.

3.1 Industrial structure

To keep the general equilibrium analysis as simple as possible, we make the following assumptions on initial conditions.

Assumption 1 *A fraction u of local intermediate good producers begins with a 'bad' quality, i.e., with a quality gap w.r.t. the international quality frontier. The remaining fraction $(1-u)$ starts with no quality gap. Formally,* $\exists\, u, \beta \in [0,1] :\ \forall m \in [0,u),\ v(m,0) = \beta v(m^*,0)$ *and* $\forall m \in [u,1),\ v(m,0) = v(m^*,0)$.

Thus the initial industrial structure is characterized by two parameters: the proportion u of 'bad' firms and their quality gap β w.r.t. the international quality frontier.

Assumption 2 *We normalize at the beginning the international quality frontier for each sector:* $\forall m^* \in [0,1),\ v(m^*,0) = v^*(0)$.

Since over time both 'good' and 'bad' firms may learn, and the international quality frontier moves, we define the ratio of local to international quality at time t, $\beta_L(t) \equiv \frac{v(L,t)}{v^*(t)}$ and $\beta_H(t) \equiv \frac{v(H,t)}{v^*(t)}$, for 'bad' and 'good' firms, respectively[14]. We also denote by $p_L(L,t)$ and $p_L(H,t)$ the lower price threshold and by $p_H(L,t)$ and $p_H(H,t)$ the higher price threshold, for the two types of firms at a given point in time[15].

4 Static Equilibria

We define an equilibrium as a collection of prices and quantities such that consumers maximize utility, both intermediate and final good producers maximize profits and all markets clear. We call an equilibrium symmetric when firms with the same quality level make the same choices. We restrict our attention to symmetric equilibria[16]. At a generic time t, the above

[14] Thus Assumption 1 means $\beta_L(0) = \beta$ and $\beta_H(0) = 1$. In some cases we relax assumption 1 to allow for $\beta_H(0) \leq 1$.

[15] Observe that $p_H(L,t) < p_L(H,t) \Leftrightarrow \frac{\beta_L(t)}{\beta_H(t)} < \frac{1}{\{[1+\tau(t)](1+a)\}^2}$, where $\frac{\beta_L(t)}{\beta_H(t)}$ denotes the ratio of 'bad' firms' quality to 'good' firms' quality.

[16] In a previous version of the paper, available from the authors upon request, we studied, under an increasing returns to scale technology, the case in which all local firms have the same quality level, i.e., $u = 1$, and we proved three results: first, there exists a unique (symmetric) equilibrium, in which all intermediate goods producers sell locally at the same price and there is no international trade; second, there may exist (asymmetric) equilibria

stated notational conventions apply, with the omission of the time index for the sake of the present section.

We first discuss the symmetric equilibrium of our economy under autarky. We next let our small economy be open, by assuming that it interacts with the rest of the world. This latter is not influenced by the small economy and it works exactly in the same way as that one would, should it be in autarky and have $u = 0$.

4.1 Equilibrium under autarky

Proposition 1 ***(Autarkic symmetric equilibrium)*** *There exists a unique symmetric equilibrium under autarky.*

Proof See Appendix A. ■

From the proof of Proposition 1 it is immediate to derive production and consumption patterns in the autarkic equilibrium:

$$y_A(1) = \left[uv(L)^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} + (1-u)v(H)^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}\right]^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}} \tag{20}$$

$$y_A(L) = \left\{u + (1-u)\left[\frac{v(L)}{v(H)}\right]^{-\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}\right\}^{-\alpha} \tag{21}$$

$$y_A(H) = \left\{u\left[\frac{v(L)}{v(H)}\right]^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} + (1-u)\right\}^{-\alpha} \tag{22}$$

The autarkic consumption level $y_A(1)$ is a decreasing function of u and an increasing function of both $v(L)$ and $v(H)$ (and therefore, given $v(H)$, of the domestic 'bad' to 'good' quality ratio). It is also an increasing function of σ, since a higher elasticity of substitution allows a more intensive use of 'good' inputs and a less intensive use of 'bad' ones. As it was to be expected, $y_A(1)$ does not depend on either τ or a.

The autarkic production patterns of intermediate good producers have the following properties: $y_A(L) < 1 < y_A(H)$; both $y_A(L)$ and $y_A(H)$ are increasing functions of u; $y_A(L)$ is increasing in $\frac{v(L)}{v(H)}$; $y_A(H)$ is decreasing in $\frac{v(L)}{v(H)}$; $y_A(L)$ is decreasing in σ; $y_A(H)$ is increasing in σ. Thus the

such that only a measure $n \in (0, 1)$ of intermediate good producers are active and they even export, whereas the remaining intermediate firms stay closed and the corresponding goods are imported; third, the asymmetric trade equilibria tend to be Pareto-superior to the symmetric no-trade one from a static point of view.

difference in production between 'good' and 'bad' domestic firms increases with the quality gap between them, and a higher elasticity of substitution yields a more intensive use of high quality inputs (confirming analytically the intuition given above). Again, τ and a do not affect autarkic production patterns.

4.2 Equilibrium in the rest of the world

As mentioned above, when we let our small economy be open, we consider the equilibrium in the rest of the world as determined under autarky. Taking the final good produced abroad at time $t = 0$ as numeraire, i.e., setting $p(1^*, 0) = 1$, Assumption 2 and the definition of the price index P^* imply that, letting $p^*(t)$ be the common price of all intermediate goods produced abroad at time t, the initial foreign marginal cost of producing the final good is $P^*(0) = \frac{p^*(0)}{v^*(0)} = p(1^*, 0) = 1$, so that $p^*(0) = v^*(0)$. Our derivation of the autarkic equilibrium then implies that for any $t \geq 0$, foreign consumption is $y(1^*, t) = v^*(t)$, the common quantity of all intermediate goods produced abroad is $y^*(t) = 1$, prices are $p(1^*, t) = P^*(t) = 1$, $p^*(t) = v^*(t)$, and the wage rate is $w^* = \frac{\alpha(\sigma-1)}{\sigma} v^*(t)$.

4.3 Equilibrium for the small open economy

In open economy, the sharp international competition implied by the perfect substitutability of intermediate goods at different quality levels, combined with the the presence of heterogeneous local producers, significantly complicates the (symmetric) general equilibrium analysis of the model. Since we consider two types of domestic intermediate good producers, each of which has three basic alternatives (stay closed, serve just the local market or also export), and since it is easy to show that 'bad' firms cannot profitably export when 'good' ones do not, and cannot profitably stay open unless also 'good' ones can, there exist six types of structurally different potential symmetric equilibria. In Appendix B we provide a detailed analytical discussion of the issue of existence and uniqueness of each type of equilibrium. In that discussion, and in the remainder of the paper, we take initial foreign consumption as numeraire (i.e., we set $p(1^*) = 1$ in the present section and $p(1^*, 0) = 1$ in the dynamic one), thus making the previous analysis of the economy of the rest of the world directly applicable.

We can summarize the main results of Appendix B by saying that, since we are ultimately interested in the policy implications of the model from a dynamic perspective, we can safely concentrate on just two types of structurally different symmetric equilibria, summarized in the following table.

	Type of symmetric eq.	**'Good firms'**	**'Bad firms'**
ED	**Export and die**	sell locally and export	stay closed
SS	**Survive and survive**	just sell locally	just sell locally

Proposition 2 *The following results hold.*

- *If an ED equilibrium exists, then it is unique and its consumption and production patterns are*

$$y_{ED}(1) = \frac{(1-u)^{1-\alpha}p_L(H)}{P_{ED} - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}P_{ED}^{\sigma}}, \quad \text{where} \tag{23}$$

$$P_{ED} = \left\{u[(1+a)(1+\tau)]^{1-\sigma} + (1-u)[(1+a)(1+\tau)]^{\sigma-1}\right\}^{\frac{1}{1-\sigma}}$$

$$y_{ED}(L) = 0 \tag{24}$$

$$y_{ED}(H) = (1-u)^{-\alpha} \tag{25}$$

- *If tariff protection is sufficiently high, then there exists an SS equilibrium with the same production and consumption patterns as autarky, namely those described by equations (20), (21) and (22). We will call it henceforth 'autarky-like SS equilibrium'.*

- *There may exist a different SS equilibrium, which we will call 'limit price SS equilibrium', whose consumption and production patterns are*

$$y_{SS}(1) = \left[uv(L)^{-\frac{1}{\alpha}} + (1-u)v(H)^{-\frac{1}{\alpha}}\right]^{-\alpha} \tag{26}$$

$$y_{SS}(L) = \left\{u + (1-u)\left[\frac{v(L)}{v(H)}\right]^{\frac{1}{\alpha}}\right\}^{-\alpha} \tag{27}$$

$$y_{SS}(H) = \left\{u\left[\frac{v(L)}{v(H)}\right]^{-\frac{1}{\alpha}} + (1-u)\right\}^{-\alpha} \tag{28}$$

Proof See Lemmata 4 and 5 in Appendix B. ■

Since we have already discussed the autarkic equilibrium, and therefore know the properties of an 'autarky-like SS equilibrium', let us now make a couple of observation on the other two equilibria.

One can check that, if an ED equilibrium exists, its consumption level, given by (23), is a decreasing function of τ. The reason is that a higher tariff protection raises import prices and lowers export prices, thus worsening the terms of trade (recall that $\tau^* = \tau$). This means that consumption under an ED equilibrium is highest under free trade, in the sense of $\tau = 0$. Further, the less exporters there are (the higher u), the more each of them produces, as shown analytically by (25) and implied intuitively by full employment in equilibrium. Since intermediate goods production involves decreasing returns to scale, the result is that, if an ED equilibrium exists, its consumption level is also a decreasing function of u.

While necessary and sufficient conditions for existence of an ED equilibrium are quite complicated, and we spell them out in Appendix B (Lemma 4), we may recall here that a necessary condition for its existence is that the domestic industrial structure is sufficiently heterogeneous, in the sense that $v(L)$ is sufficiently lower than $v(H)$[17]. Otherwise, if high quality firms find it optimal to export, low quality firms would not find it optimal to stay closed.

Turning to the 'limit price SS equilibrium', notice that it derives its name from the fact that intermediate good producers are forced by international competition to increase production (with respect to autarky), in order to be able to sell at a lower price, namely at the limit price $p_H(m)$, for $m = L, H$. If they were to produce less then $y_{SS}(m)$, for $m = L, H$, then the market price of their product would be higher than $p_H(m)$ and nobody would buy from them.

Observe further that $y_{SS}(1)$, $y_{SS}(L)$ and $y_{SS}(H)$ can be obtained by $y_A(1)$, $y_A(L)$ and $y_A(H)$, respectively, by simply setting $\sigma = 0$. Although we assume throughout the paper that $\sigma > 1$, we may notice that mathematically $y_A(1), y_A(L)$ and $y_A(H)$ are continuous and monotonic functions of σ even in the range $\sigma \leq 1$. From our analysis of the autarkic equilibrium, we then derive the following corollary.

Corollary 1 *$y_{SS}(1) < y_A(1)$, $y_{SS}(L) > y_A(L)$ and $y_{SS}(H) < y_A(H)$.*

Thus, in particular, if, for a given tariff value, both an 'autarky-like SS equilibrium' and a 'limit price SS equilibrium' exist, then the former

[17] The condition is $\frac{v(L)}{v(H)} < K_5$, where $K_5 \in (0, 1)$ is a constant.

Pareto-dominates the latter[18]. Yet it is easy to show that the 'limit price SS equilibrium' may exist for lower tariff values, for which the 'autarky-like SS equilibrium' does not exist.

4.4 Autarky versus Free Trade

Let us now compare, when an ED equilibrium exists, its consumption level with the autarkic one: i.e, let us compare $y_A(1)$ with $y_{ED}(1)$. The best way to think of this comparison (and indeed the way that gives an ED equilibrium its best chances) is as one between the the two polar cases of high protection, which isolates the economy from the rest of the world, and of free trade, in the sense of zero tariff. We ask two questions.

- First, we want to investigate the space of industrial structures to understand when free trade is better than autarky (to be precise, for which industrial structures an ED equilibrium under free trade exists and yield a higher consumption than autarky).
- Second, since consumption in autarky and in an 'autarky-like SS equilibrium' is the same, we focus on this latter equilibrium and ask an additional question: for those industrial structures for which free trade is not better than autarky (either because an ED equilibrium does not exist, or because it yields a lower consumption), what is the minimum degree of tariff protection, which ensures the existence of an 'autarky-like SS equilibrium'?

Defining $K \equiv \left\{ \frac{1-u}{u} \left[\left(\frac{u(1+a)^{2(1-\sigma)}+(1-u)}{1-u} \right)^{\frac{1}{\alpha+\sigma(1-\alpha)}} - 1 \right] \right\}^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}}$, equations (20) and (23) yield

$$y_{ED}(1) > y_A(1) \iff \frac{v(L)}{v(H)} < K. \tag{29}$$

Notice that $0 < K < 1$ and that K is decreasing in a[19]. Therefore, we have the following proposition.

[18] This is intuitive because, algebraically, a 'limit price SS equilibrium' corresponds to the autarkic equilibrium that would hold if there were no possibility of substitution between different intermediate inputs.

[19] To see that $K < 1$ calculate it for $a = 0$ and then observe that in that case a sufficient condition for $K < 1$ is $1 - (1-u)^{\frac{1}{\alpha+\sigma(1-\alpha}} < u$, which is always satisfied for $u < 1$, due to strict convexity of the left hand side, to continuity and to equality of the two sides for $u = 0$ and $u = 1$.

Proposition 3 *If under free trade an ED equilibrium exists, then it is Pareto-superior to the autarkic equilibrium if and only if the industrial structure is sufficiently heterogeneous.*

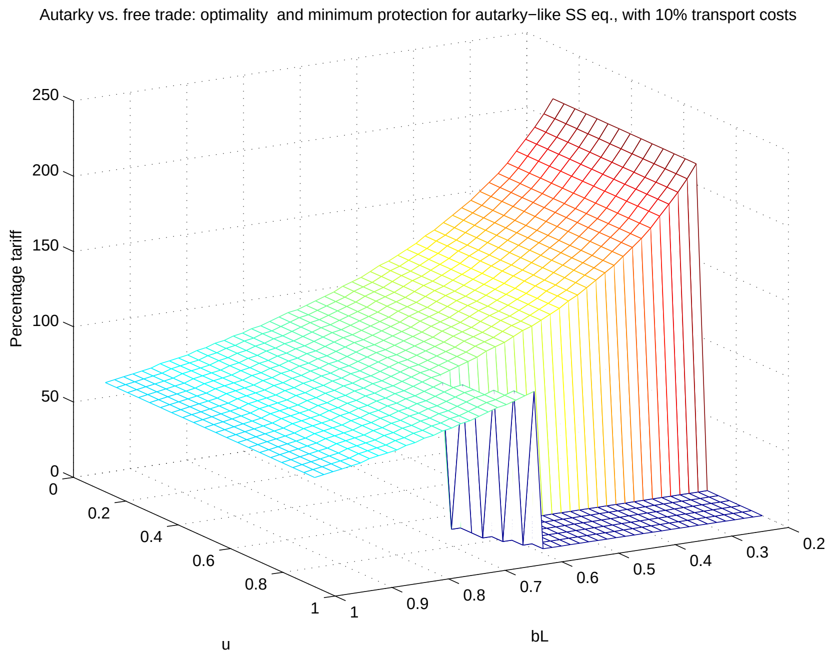
Proof The result immediately follows from equation (29). ■

Remark 1 *As long as an ED equilibrium under free trade exists, a reduction in transportation costs, which is a simple way of thinking of globalization, makes free trade preferred to autarky for a wider range of industrial structures.*

Remark 2 *As we have noticed above, under free trade an ED equilibrium exists only if the industrial structure is sufficiently heterogeneous. Therefore, heterogeneity of the domestic industrial structure plays the double role of generating gains from trade and of allowing them to be reaped in equilibrium.*

To have a visual image of the industrial structures for which an ED equilibrium under free trade both exists and is Pareto-superior to autarky, let us normalize $v(H) = v^* = 1$, so that $\frac{v(L)}{v(H)} = \beta_L$, and then compare free trade and autarky over the $u - \beta_L$ plane. The following figure plots a zero in the area where the ED equilibrium under free trade both exists and yields a higher consumption than autarky. In the remaining area, it plots the minimum tariff, above which an 'autarky-like SS equilibrium' exists[20]. The figure is drawn for the following parameter values: $\alpha = 0.9$, $\sigma = 4$ and $a = 0.1$.

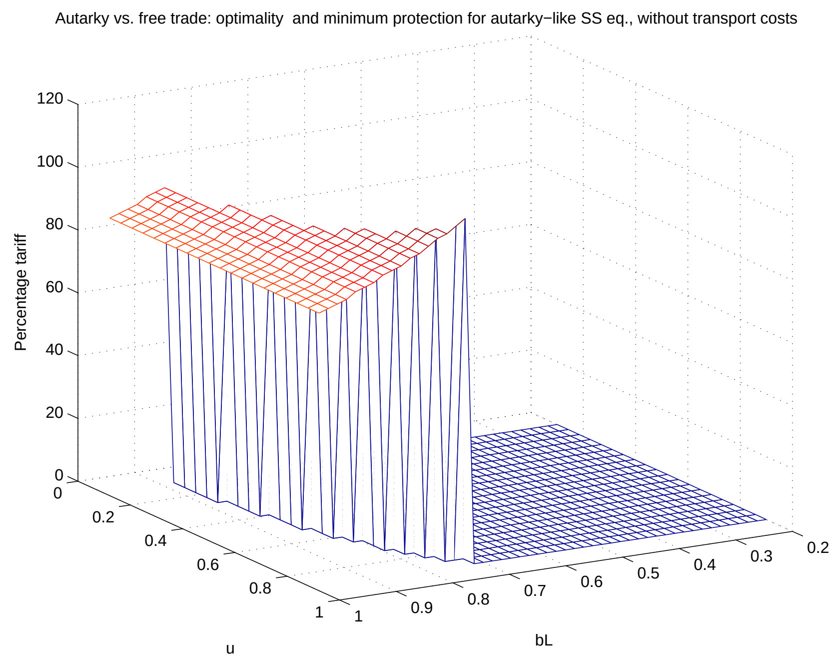
[20]Observe that, over such area, this minimum tariff is also an optimal tariff (from a static point of view), because $y_A(1)$ does not depend upon τ. Since $y_{SS}(1)$ does not depend upon τ either, and we have shown that $y_{SS}(1) < y_A(1)$, this optimality would still hold if we extended the comparison to the 'limit price SS equilibrium'. Yet in that case the minimum SS-compatible tariff (the minimum tariff that allows survival of all domestic producers) would be lower. We will come back to this point in the dynamic analysis.



One can observe that free trade turns out to be superior to protectionism only on a small area, corresponding to industrial structures with very high values of u and low values of β_L. Outside of this area, either an ED equilibrium under free trade does not exist, or it yields a lower consumption level than the 'autarky-like SS equilibrium'. Observe further that the minimum tariff required for existence of an 'autarky-like SS equilibrium' is quite high, and it is a decreasing function of β_L, whereas it does not depend on u[21]. This is not surprising, since protection must be higher, if one wants to let firms with a higher quality gap survive, and it must be substantial, if one wants to make all firms produce the same quantities as under autarky. Moreover, in a model in which local perfect substitutes for international goods are available, the presence of transport costs raises import prices and lowers export prices, thus worsening the terms of trade and making international trade less desirable than local production in most cases. Yet, when there are several backward firms and they are very backward, protectionism would force the economy to rely heavily on very low quality goods, and the quality advantage offered by international trade become overwhelming with respect to their cost.

[21]For this reason, to avoid to plot extremely high tariff levels, the figure is only plotted for $\beta_L \geq 0.2$. Further, to avoid border effects and to ensure that assumption $a < 1/u$ holds, it is only plotted for $u \in [0.1,\ 0.9]$.

The next figure shows how these results change if, keeping all other values constant, we set $a = 0$. In this case, which corresponds to the absence of transportation costs, free trade is superior to protectionism almost everywhere, but for very high values of β_L[22]. Thus in this model transport costs play a crucial role in determining, in the space of industrial structures, the relative areas of optimality of free trade vs. protectionism. If we think of globalization as a reduction in transportation costs, we can easily interpret such results as showing that globalization has rendered free trade more attractive for a wide variety of countries, at different stages of development and thus with very different industrial structures.



To complete the analysis, we can further observe that the area of optimality of protectionism becomes wider as decreasing returns to scale become more pronounced, because this makes production of great quantities for export less efficient, and as $v(H)$ decreases (given $v^* = 1$), because this reduces domestic heterogeneity and thus decreases the gains from trade. The elasticity of substitution σ does not significantly affect the area of optimality of

[22]There is still a small area, marked by a downward sloping curve in the $u - \beta_L$ space, where protectionism is optimal. In this area the minimal tariff allowing an autarkic-like SS equilibrium is again a decreasing function of β_L, but it is naturally shifted upwards compared to the case with positive transport costs.

protectionism, but it rather changes the slope of the minimum tariff yielding an 'autarky-like SS equilibrium' as a function of β_L. Finally, v^* has only an effect on the level of consumption, but neither on the optimality of any policy nor on the required tariff.

4.5 Degree of tariff protection

From the above figures we have gained an idea of the degree of tariff protection needed for an 'autarky-like SS equilibrium' to exist. Yet in the dynamic analysis of the next section we discuss a trade policy based on the minimum SS-compatible tariff, that is, on the minimum tariff that allows survival of all domestic intermediate good producers. The reason to do this is that policy makers may face obstacles of various kinds to maintain for a long time tariff rates at such high levels as to completely isolate their country from the rest of the world. Much more plausible and relevant for the dynamic analysis is a temporary protection policy, for instance based on the infant industry argument. Before turning to the dynamics, it is then interesting to ask what is the minimum degree of tariff protection that allows existence of an SS equilibrium (either of the 'autarky-like' type or of the 'limit price' one) for different industrial structures. Systematic numerical analysis yields the following results.

- The minimum SS-compatible tariff does not depend on u.
- It is a decreasing function of the ratio $v(L)/v(H)$, continuous almost everywhere.
- There exists a threshold value of $v(L)/v(H)$, below which only an 'autarky-like SS equilibrium' exists and above which also a 'limit price' one exists. The minimum SS-compatible tariff is discontinuous at the threshold.
- As $v(L)/v(H)$ converges to 1, the minimum SS-compatible tariff converges to 0[23].

[23]To have a numerical feeling, given $v^* = 1$, $\alpha = 0.9$, $\sigma = 4$ and $a = 0$, the threshold value of $v(L)/v(H)$ is around 0.7; crossing it makes the minimum SS-compatible tariff drop from more than 100% to a few percentage points. Transportation costs do not change the threshold value of $v(L)/v(H)$, but reduce the minimum tariff required for existence of both types of SS equilibrium. In particular, they may make the minimum tariff drop directly to zero at the threshold.

Thus, for a very heterogeneous industrial structure, survival of all domestic firms is only possible under a very high degree of protection. For a more homogeneous one, it becomes possible under much lower tariff values. Eventually, as the domestic quality gap closes, tariff protection is no longer necessary at all.

This explains why, as we discuss in the next section, if the learning dynamic is such that survival of all domestic firms induces local convergence, then a trade policy based on the minimum tariff that allows survival of all domestic firms requires a degree of protection that decreases over time and eventually drops to zero.

5 Simulation Exercises on Dynamics

We make two basic assumptions about the dynamics of quality improvement: the first is that a firm's quality improvement is a concave function of its own quality (i.e., learning exhibits decreasing returns to own quality); the second is that firms learn to a relevant degree through localized network interaction with other firms.

The first assumption means that to improve a good product is harder than to improve a bad one. The second one is well supported by recent empirical results. For instance, Keller (2002) finds that international technology diffusion among OECD countries is geographically localized: specifically, his estimations imply that the distance at which technology spillovers are halved lies between a lower bound of 162 kilometers and an average of 1200 kilometers in his preferred specification[24]. Using data on European Regions, Bottazzi and Peri (2003) find that R&D spillovers diffuse within 300 kilometers from the source region, but no effect spreads further than that[25]. The evidence involves both between[26] and within industry spillovers[27].

To capture these two ideas, recalling that $v(m, t)$ denotes good m's domestic quality, $y(m, t)$ its production, and $D(t) \subseteq [0, 1)$ the set of active domestic intermediate good producers, all of them at time t, we assume the following learning dynamic

[24]He also finds that technology diffusion has become less localized and more international over time, especially from the Seventies.

[25]Notice that while Keller studies the effect of R&D on countries' productivity, Bottazzi and Peri study its effect on countries' innovation.

[26]Glaeser et al. (1995), Kugler (2005).

[27]For instance, Foster and Rosenzweig (1995), and Goolsbee and Klenow (2002).

$$v(m,t+1) = v(m,t) + v(m,t)^{\varphi} \left[\int_{D(t)} y(i,t)v(i,t)\,\mathrm{d}i \right]^{1-\varphi-\epsilon} \tag{30}$$

where $\varphi \in (0,1)$ and $\epsilon \in (0, 1-\varphi)$ are parameters.

Our first assumption (high quality goods are harder to further improve than low quality ones) is captured by $v(m,t)^{\varphi}$, with $\varphi \in (0,1)$. The term by which it is multiplied captures the local network effect: each firm learns from other firms active in its local area (in our case, in its country), and it learns more the greater the mass of such firms (this captures the density of potential linkages in the local industrial network), the higher their quality (there is more to learn from interaction with better firms) and the more they produce (bigger firms' knowledge spillovers are likely to be greater). Given this local network effect, different local industrial structures imply different learning dynamics[28].

The rest of the world learns through an analogous dynamic, with its corresponding quality, production and mass of active firms. Assumption $\epsilon \in (0, 1-\varphi)$ then ensures that, including both learning from own quality and from networking, the world quality frontier evolves as a concave function over time (i.e., there are decreasing returns in learning)[29].

Since, as we have already shown, domestic trade policy may trigger changes in the local industrial structure, changes that determine which firms are active and which of them export, it also has dynamic consequences on the learning ability of domestic firms. In particular, we now extend our static analysis to consider two different policies:

1. Free Trade, under which $\tau(t) = 0$ for all $t \geq 0$;

2. Temporary Protection, which requires to select, at each point in time, the minimum tariff that is necessary to keep all domestic firms active.

These policies allow us to compare an outward-oriented development strategy, more associable to contemporaneous consensus, with an import

[28] Under dynamic (30), exporting does not play an special role in improving quality except for the fact that it increases production of active firms.

[29] Notice that dynamic (30) does not reach a steady state, because learning indefinitely cumulates over time. To have a steady state, it would be enough to assume, for instance, a constant depreciation rate of technological knowledge (a firm's quality). Yet we do not need a steady state to point out the interesting aspects of the dynamic analysis, so we assume no depreciation.

substitution strategy (especially aimed at protecting infant industries), which was a common recommendation between World War II and mid Seventies.

Comparison of our two policies is most interesting when Free Trade gives rise to an ED equilibrium at any point in time and when the Paretian ranking of the two policies is reversed when we pass from the static analysis of the initial industrial structure to the dynamic analysis over an infinite time horizon[30]. To ensure that these conditions are satisfied, we carry out most of our simulations assuming $a = 0$, i.e., in the absence of transport (or adoption) costs[31]. In this case, as we have seen above, Free Trade is statically superior to Protection for most initial industrial structures.

To see how this initial, static Paretian ranking may be reversed when we consider an infinite time horizon, suppose that time discounting is very low. We show below that Temporary Protection always implies eventual convergence to the international quality frontier by all domestic firms. Free Trade implies that initially backward domestic industries never develop, and that initially advanced ones suffer from the implied shrinking of the local industrial network and converge over time to a stable quality gap from the international frontier. In other words, with very low time discounting, a dynamics with relevant local learning through network interaction, as the one assumed in equation (30), invariably favors Temporary Protection over Free Trade[32]. We then have the following formal result.

For any initial industrial structure, for which Free Trade is initially superior to Protection from a static point of view, there exists a $\bar{\rho} > 0$, such that for any $\rho < \bar{\rho}$, the present discounted value of the stream of consumption obtained in a sequence of SS equilibria under Temporary Protection is higher than that obtained in a sequence of ED equilibria under Free Trade[33].

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[30] If, under Free Trade, at some point in time no ED equilibrium exists, or even no symmetric equilibrium exists at all, then the comparison is either trivial or impossible. If, in turn, one policy is better than the other both statically (given the initial industrial structure) and dynamically, then the analysis is again trivial. Finally, if at some time t for $\tau(t) = 0$ both an ED and an SS equilibrium exist, then we focus on the former under Free Trade and on the latter under Temporary Protection. Observe that our welfare measure is always given by equation (1).

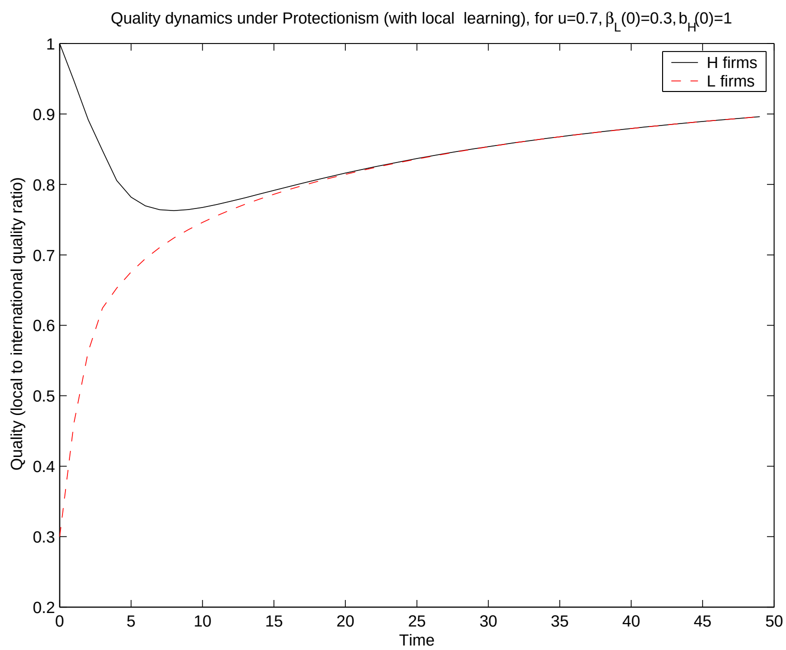
[31] We then discuss the consequences of raising a.

[32] If either there were learning by doing or learning externalities were not localized, then specialization allowed by Free Trade would obviously favor dynamic learning. We discuss below a dynamic of this second kind.

[33] In all of our numerical simulations we find that, if an ED equilibrium under Free Trade is statically superior to an SS equilibrium under Temporary Protection for the initial industrial structure, then under Free Trade at each point in time along the entire dynamic there exists an ED equilibrium. Thus, existence of ED equilibria in this case is

In other words, if the representative consumer is sufficiently patient, dynamic (30) implies that Temporary Protection is dynamically better than Free Trade, because it eventually leads to better results.

To have a visual image of how quality convergence results work, consider the following figure, which depicts the dynamic of $\beta_L(t)$ and $\beta_H(t)$ under Protectionism, for an initial industrial structure characterized by $u = 0.7$, $\beta_L(0) = 0.3$ and $\beta_H(0) = 1$, given the following parameter values: $p^*(0) = v^*(0) = 1$, $a = 0$, $\sigma = 4$, $\varphi = 0.3$ and $\epsilon = 0.1$.



One can observe that Temporary Protection first induces local convergence and then catch-up with the international quality frontier[34]. By allowing initially backward firms to survive, Temporary Protection lets them benefit from local interaction with initially advanced ones. At the same time, local interaction with backward firms prevents initially advanced ones from keeping the improvement pace of the the international quality frontier, so that their gap from it initially increases. Yet, as backward firms' quality

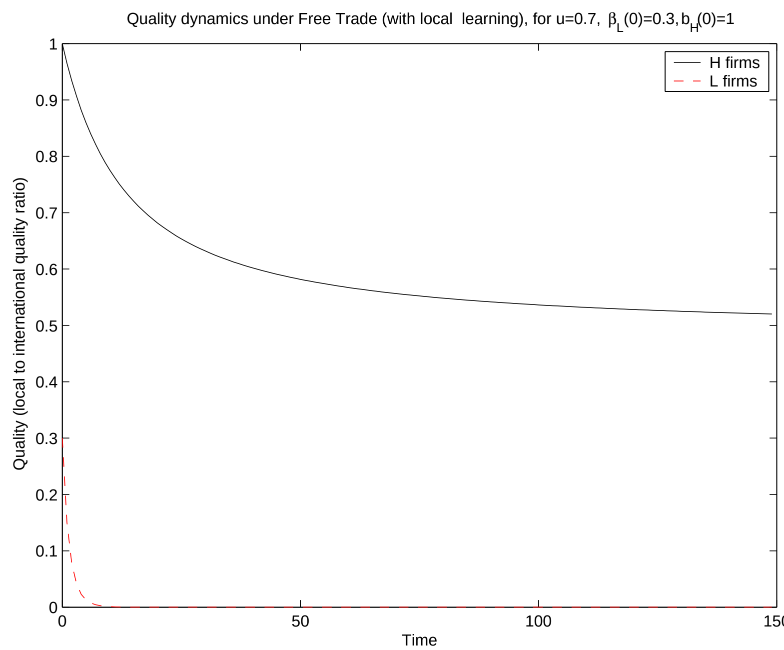
not an issue. Recall that SS equilibria always exist for a sufficiently high tariff.

[34]Although convergence to the frontier cannot be appreciated in the figure, which is only drawn until $t = 50$ to highlight the initial phase of local convergence, it is clearly confirmed by simulations run over a longer time span.

improves, the entire domestic industrial structure enjoys the faster growth pace allowed by its relative backwardness under the assumption of decreasing returns in learning. This makes the quality gap converge to zero, i.e., induces catch-up with the frontier.

This is a general pattern under Temporary Protection. An improvement of the initial industrial structure, either in the form of a lower u or of a higher $\beta_L(0)$, reduces the initial competitive cost paid by advanced firms.

It is interesting to compare this dynamics with the one implied by Free Trade, which is depicted in the next figure for the same initial industrial structure and the same parameter values[35].



It is immediate to notice that, since Free Trade pushes initially backward firms out of the market, the corresponding domestic industries do not experience any further development, so that $\beta_L(t)$ rapidly converges to zero. On the other side, since initially advanced firms can count on a smaller local network than their international counterparts, their gap from the frontier initially increases. Yet, the fact that they now export makes each of them produce more, so that, although active domestic firms are now less in

[35] The only difference is that, since in this case the initial phase is less interesting, the figure has been plotted until $t = 150$ to better highlight convergence patterns.

number, they learn more from each other and eventually catch up with the improvement pace of the international quality frontier, thus stabilizing their gap from it[36].

This is again a general pattern under Free Trade. An improvement of the initial industrial structure in the form of a lower u (at least within the range in which at the beginning Free Trade is statically superior to Protection) has the expected effect of reducing the initial competitive cost imposed to advanced firms by the shrinking of the local industrial network, and thus it lets them converge to a lower quality gap from the frontier (i.e., to a higher β_H)[37].

Once we have understood how this learning dynamic works, the following formal result clearly follows. Let $c_{FT}(t)$ and $c_{TP}(t)$ be time t consumption under Free Trade and under Temporary Protection, respectively[38]; call $U_{FT} \equiv \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho}\right)^t \ln c_{FT}(t)$ and $U_{TP} \equiv \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho}\right)^t \ln c_{TP}(t)$; denote $\Delta U(t) \equiv \sum_{j=0}^{t} \left(\frac{1}{1+\rho}\right)^j [\ln c_{TP}(j) - \ln c_{FT}(j)]$; and define μ a quadruple $(u, \beta_L(0), \beta_H(0), \rho)$ such that, under dynamic (30), a sequence of ED equilibria under Free Trade exists, and such that $c_{FT}(0) > c_{TP}(0)$ but $U_{TP} > U_{FT}$.

Then $\forall \mu$, $\exists \bar{t}$ such that $\forall t < \bar{t}$, $\Delta U(t) < 0$, and $\forall t > \bar{t}$, $\Delta U(t) > 0$.

In words, for any initial industrial structure, for which Free Trade is statically Pareto-superior to Protection at the beginning (and thus induces a sequence of ED equilibria), and for any value of ρ, for which Temporary Protection is dynamically superior to Free Trade (when we sum discounted utility over an infinite time horizon), there exists a time $\bar{t}$, such that the partial sum of the difference in discounted utility between the two policies

[36] While from the figure it may still be unclear whether $\beta_H(t)$ converges or not, repeating the dynamic simulation for a much higher t indeed confirms its convergence to some $\beta_H > 0$.

[37] Within the range of initial industrial structures considered, an increase in $\beta_L(0)$ has no effects under Free Trade, because in an ED equilibrium initially backward firms are not active.

[38] Observe that, except for the time index, $c_{FT}(t)$ is given by equation (23), whereas $c_{TP}(t)$ may be either given by (20) or by (26), depending on whether the 'autarky-like SS equilibrium' exists for a lower tariff than the 'limit price SS equilibrium' or the other way around. Our static analysis implies that the former is the case when there is sufficient local heterogeneity, whereas the latter is the case for more homogeneous industrial structures, which is typically the case after a period of protection. It also implies that in this case the minimum SS-compatible tariff decreases over time to zero: that is why we call this policy Temporary Protection.

is negative until $\bar{t}$ and positive afterwards.

In light of this result, one interesting way of comparing Free Trade and Temporary Protection across different initial industrial structures is to ask how $\bar{t}$ changes with initial conditions. Suppose that the policy maker is myopic, in the sense that, although aware of the representative consumer's time discount rate, it only plans over a finite horizon. We then ask the following questions: in a situation in which we know that the long run optimum is granted by Temporary Protection (because it allows the full development of the domestic industrial structure), but in which Free Trade is optimal in the short run (because initial domestic heterogeneity is high), what is the planning horizon that would induce a myopic policy maker to choose Temporary Protection? How does it change across different initial industrial structures[39]? How do patience and transport costs affect it?

In the following table, we compare the values of $\bar{t}$ for four different initial industrial structure and two degrees of patience[40].

$\bar{t}$	$u = 0.2$ $\beta_L(0) = 0.3$	$u = 0.2$ $\beta_L(0) = 0.7$	$u = 0.7$ $\beta_L(0) = 0.3$	$u = 0.7$ $\beta_L(0) = 0.7$
$\rho = 0.05$	30	12	22	7
$\rho = 0.1$	∞	14	39	7

The planning horizon and cost of protection are highly sensitive to the initial characteristics of the industrial structure and to consumer patience. Fix first the level of patience. For a given mass of backward firms (u), the gains from protection *decrease* with the level of backwardness (the greater $\beta_L(0)$, the lower $\bar{t}$)[41]. This simply comes from the fact that the cost of protecting backward firms is lower when these firms are not too backward, because in that case both local and international catch-up are fast.

On the other hand, for a given production quality of backward firms ($\beta_L(0)$), the gains from protection *increase* with the level of backwardness (the greater u the lower $\bar{t}$). When the mass of backward is greater, Free

[39] Observe that a similar comparison of the relative advantage of the two policies across industrial structures might be done in terms of $\bar{\rho}$ rather than of $\bar{t}$. In that case, we would not need to consider a myopic policy maker, but our choice is motivated by the fact that the main qualitative results would be the same, that it is more convenient numerically to work on $\bar{t}$ and that we find the idea of a myopic policy maker interesting per se.

[40] As in the previous figures, the other parameters are $\beta_H(0) = 1$, $p^*(0) = v^*(0) = 1$, $a = 0$, $\sigma = 4$, $\varphi = 0.3$ and $\epsilon = 0.1$. The term ∞ appears because the quadruple $(u, \beta_L(0), \beta_H(0), \rho) = (0.2, 0.3, 1, 0.1)$ in not a μ, since $U_{TP} < U_{FT}$.

[41] Recall that we measure the level of backwardness of an initial industrial structure along two dimensions: the mass of backward firm u and the ratio of their quality to the international frontier $\beta_L(0)$.

Trade pushes a greater number of firms out of business. Thus the local industrial network, from which advanced firms may learn, further shrinks, making them converge to a lower β_H. This raises the cost of Free Trade more than that of Temporary Protection, due to fast local and international catch-up in the latter case, hence the result.

This results is interesting, because it enriches our understanding on what kind of industrial structure is more worth protecting. In terms of the old debate on infant industries, the payoff of protection is higher when there are many backward firms but it becomes less beneficial when these firms are very backward. When both dimensions of backwardness are considered, the industrial structure that is most worthy to protect is that composed of "many 'advanced' backward firms"[42].

Observe that, for a given industrial structure, the gains from protection increase with the level of patience (the lower ρ, the lower $\bar{t}$).

Let us now allow for the possibility that also domestic advanced firms start with an initial quality gap from the international frontier, a case that indeed applies to several developing countries. Ceteris paribus, a reduction in $\beta_H(0)$ reduces $\bar{t}$: contrary to what one could expect, it now takes a shorter period for Temporary Protection to lead to a higher utility level. This depends on the fact that a lower $\beta_H(0)$ implies a higher homogeneity of the initial industrial structure, which, as discussed above, reduces the relative gains to Free Trade.

When we add some transportation or adoption cost, this obviously reduces the gains from trade and thus favors protection. Still, for those combinations of industrial structures and time discount rate, for which Free Trade is statically superior to Protection at the beginning, but Temporary Protection is dynamically superior to Free Trade over an infinite horizon, the finite horizon $\bar{t}$ necessary to appreciate the superiority of Temporary Protection becomes shorter, but otherwise responds to industrial structure characteristics and to patience in the same way described above[43]. If we interpret again globalization as a reduction of a, these results may help explain changes in the consensus on the benefits of protecting backward firms: with lower transport costs, the horizon over which Temporary Protection appears superior becomes longer, so that the ability of such policy to command political consensus decreases.

[42] Among the four industrial structures considered in our numerical exercise, this is the case of $u = 0.7$ and $\beta_L(0) = 0.7$.

[43] To have a numerical feeling, with $u = 0.8$, $\beta_L(0) = 0.3$, $\beta_H(0) = 1$ and $\rho = 0.05$, passing from $a = 0$ to $a = 0.1$ makes such horizon pass from $\bar{t} = 19$ to $\bar{t} = 8$. With $\beta_L(0) = 0.6$ these two values become, respectively, $\bar{t} = 10$ and $\bar{t} = 3$.

6 Conclusions

We investigate the sensitivity of benefits from trade policy to initial characteristics of the industrial structure in situations where production quality upgrading relies upon local interactions with other firms. We focus on the role of localized learning externalities, motivated by both its own interest and by available empirical evidence, and we assume a learning dynamic that tends to favor temporary protection over free trade. We investigate then how the relative advantages of the two policies change when applied to different initial industrial structures, how they depend on patience, and of how farsighted a policy maker should be to choose in each case the dynamically superior policy. Thus our assumptions, rather than biasing the results, make them more interesting.

We model a small open economy with heterogenous firms, distinguishing a horizontal and a vertical dimension of heterogeneity (firms produce different kinds of goods and produce them at different quality levels). We show that both dimensions affect the relative advantage of trade policies. We find a small open economy framework, in which development mainly depends upon learning, particularly suited to the study of developing economies. We thus assess the relative advantage of trade openness for developing countries with different industrial structures.

Our contribution to the debate between supporters of an outward-oriented development strategy, more associable to contemporaneous consensus, and of an import substitution strategy (especially aimed at protecting infant industries), which was a common recommendation between World War II and mid Seventies, consists in arguing that the choice should be context-dependent.

We find that free trade is preferred to autarky when an industrial structure is sufficiently heterogeneous. The level of heterogeneity required for free trade to Pareto-dominate temporary protection increases with transport costs. We also find that transport costs reduce the optimality of free trade in a dynamic setting. These results may help explain changes in the consensus on the benefits of protecting backward firms: with lower transport costs, the horizon over which temporary protection appears superior becomes longer, so that the ability of such policy to command political consensus decreases.

A main result emerging from our analysis is that the benefits of protection depend upon the level of backwardness in the following way: for a given mass of backward firms, the relative gains from protection increase with the quality of backward firms (the cost of protection is lower) and decrease with the quality of advanced firms (a lower level of heterogeneity reduces the benefits from free trade). On the other hand, for given production quality levels, the relative advantage of protection increases with the mass of backward firms. According to these results, for instance, the gains to protection are much higher for a quite homogeneous, not too backward industrial structure than for a heterogeneous one, with a few very backward firms and many relatively advanced firms.

Our findings do not constitute an overall assessment of the relative desirability of temporary protection vs. free trade. Rather, they specify how the dynamic costs and benefits of these two policies depend on several characteristics of the country to which they are applied, of its development process, and of the world trading environment. We thus see this work as a starting point for a new wave of careful and critical research on an old theme, rather than as a point of arrival.

To focus on the interaction between industrial structure and local learning externalities (with decreasing returns in learning), we abstract not only from individual incentives to innovate, but also from any other kind of learning externalities. As a result, we find that temporary protection induces, first technological convergence among local firms and then global convergence to the international frontier, whereas free trade does not allow a country to catch-up to the frontier implying a loss of development opportunities.

If, by contrast, we postulated a relevant role for either learning by doing or for learning through trade (e.g., by exporting), then free trade would tend to be dynamically superior to protection because it allows specialization and export, which in that case would stimulate technological improvement[44]. On one side, the empirical literature offers mixed evidence on learning by exporting[45]. On the other side, there is abundant theoretical literature on trade and trade policy under both learning by doing and by exporting[46]. Our work complements this literature by incorporating local network effects. In future research it will be interesting to analyze all these learning sources in a more integrated framework.

[44]Simulations carried out under a learning by exporting dynamic show that, even in the case in which Free Trade is superior to Protectionism both statically and dynamically, their welfare difference ($U_{FT} - U_{TP}$) depends positively on $\beta_L(0)$ and negatively on u.

[45]For instance, Clerides et al. (1998) for a set of Colombian, Mexican and Moroccan manufacturing plants, and Bernard and Jensen (1999) and Arnold and Hussinger (2005) for US and German firms, respectively, do not support this hypothesis, whereas Kraay (1999) for China, Bigsten et al. (2004) for a sample of African countries and Albornoz and Ercolani (2005) for Argentina present some evidence supporting it.

[46]Just to mention two contributions, see Krugman (1987) and Brezis et al. (1993).

Appendix A: Proofs of Lemma 1 and Proposition 1

Proof of Lemma 1

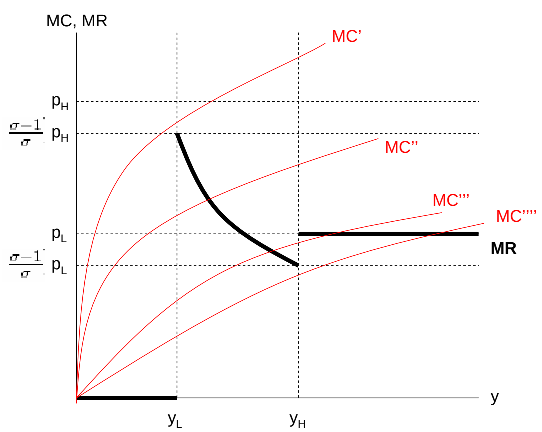
When deciding, each firm m considers other firms' choice and all equilibrium variables as given. To determine the shape of the profit function, and therefore the optimal choice, we need a closer inspection to MC and MR. From (18) and (19) we know that

$$MR(y(m))\begin{cases} 0 & , \quad \text{if } y(m) < y_L(m) \\ \frac{\sigma-1}{\sigma} y(m)^{-\frac{1}{\sigma}} [v(m)P]^{\frac{\sigma-1}{\sigma}} [p(1)y(1)]^{\frac{1}{\sigma}} & , \quad \text{if } y(m) \in [y_L(m), y_H(m)) \\ p_L(m) & , \quad \text{if } y(m) \geq y_H(m) \end{cases} \tag{31}$$

and

$$MC(y(m)) = \frac{w}{\alpha} y(m)^{\frac{1-\alpha}{\alpha}} \tag{32}$$

Observe that MC is concave if $\alpha \in \left(\frac{1}{2}, 1\right)$, convex otherwise. Observe further that $\lim_{y(m)\searrow y_L(m)} MR(y(m)) = \frac{\sigma-1}{\sigma} p_H(m)$ and $\lim_{y(m)\nearrow y_H(m)} MR(y(m)) = \frac{\sigma-1}{\sigma} p_L(m)$. The following figure, drawn for $\alpha \in \left(\frac{1}{2}, 1\right)$ and for τ sufficiently high so that $\frac{\sigma-1}{\sigma} p_H(m) > p_L(m)$ gives an idea of how MR and MC may be. The figure depicts, for a given MR curve (bold and black), several MC curves (thin and red). From a partial equilibrium perspective, one might think of them as obtained by changing w and letting all other equilibrium variables unchanged. Such perspective is useful to understand the proof of Lemma 1, although we then abandon it to turn to general equilibrium.

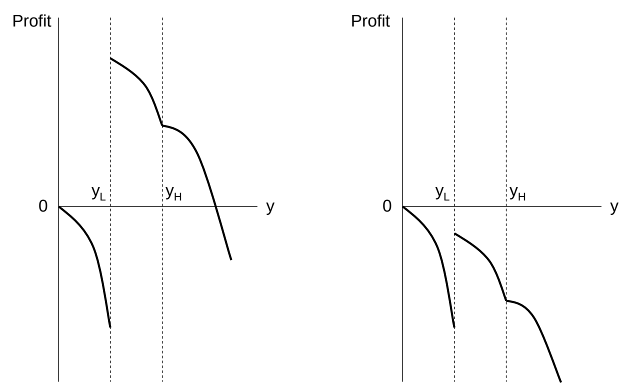


A careful analysis of this and of an analogous figure for the case in which $\frac{\sigma-1}{\sigma} p_H(m) < p_L(m)$ yields the following four possibilities.

1. If, for any $y(m) \geq 0$, $MC(y(m)) \geq MR(y(m))$, then firm m is either not active or, if and only if $\pi(y_L(m)) \geq 0$, it sells

$$y_L(m) = p_H(m)^{-\sigma}[v(m)P]^{\sigma-1}p(1)y(1) \tag{33}$$

at $p_H(m)$. This is the case with MC' in the above figure. The next one illustrates two possible profit functions in this case.



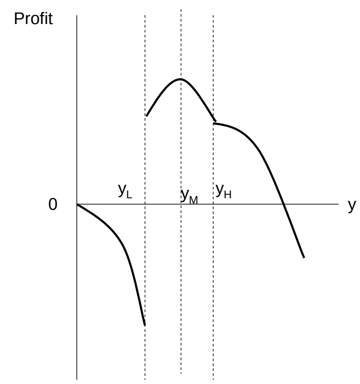
2. If $MC(y(m))$ and $MR(y(m))$ cross only once for strictly positive quantities, and if they cross in the open interval between $y_L(m)$ and $y_H(m)$, i.e., if $MC(y_L(m)) < \lim_{y(m)\searrow y_L(m)} MR(y(m))$ and $MC(y_H(m)) \geq \lim_{y(m)\searrow y_H(m)} MR(y(m))$, then there exists a unique (global) profit maximizer, $y_M(m) \in (y_L(m), y_H(m))$. Such quantity is entirely sold on the local market at price $p_M(m)$. Given that within this range, the equality between MC and MR is sufficient to ensure optimality, we can derive from (32) and (31) that:

$$y_M(m) = (\frac{\sigma-1}{\sigma}\frac{\alpha}{w})^{\frac{\alpha\sigma}{\alpha+\sigma(1-\alpha)}}[v(m)^{\sigma-1}P^{\sigma}y(1)]^{\frac{\alpha}{\alpha+\sigma(1-\alpha)}} \tag{34}$$

and

$$p_M(m) = (\frac{\sigma}{\sigma-1}\frac{w}{\alpha})^{\frac{\alpha}{\alpha+\sigma(1-\alpha)}}[v(m)^{\sigma-1}P^{\sigma}y(1)]^{\frac{1-\alpha}{\alpha+\sigma(1-\alpha)}} \tag{35}$$

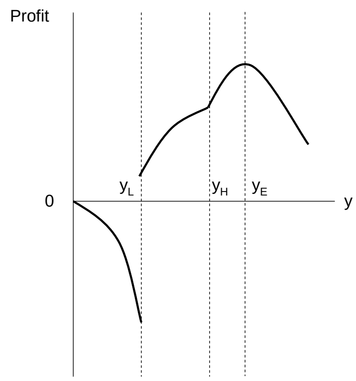
This is the case with MC'' above. The next figure illustrates the profit function in this case.



3. If between $y_L(m)$ and $y_H(m)$ $MC(y(m))$ lies below $MR(y(m))$, and crosses it afterwards, i.e., if $MC(y_H(m)) \leq \lim_{y(m) \nearrow y_H(m)} MR(y(m))$, then there exists a unique (global) profit maximizer, $y_E(m) > y_H(m)$. Such quantity is sold at price $p_L(m)$, partly on the local market, which absorbs $y_H(m)$, and for the remaining part, $y_E(m) - y_H(m)$, it is exported. In this case the choice to export induces marginal cost pricing, which yields

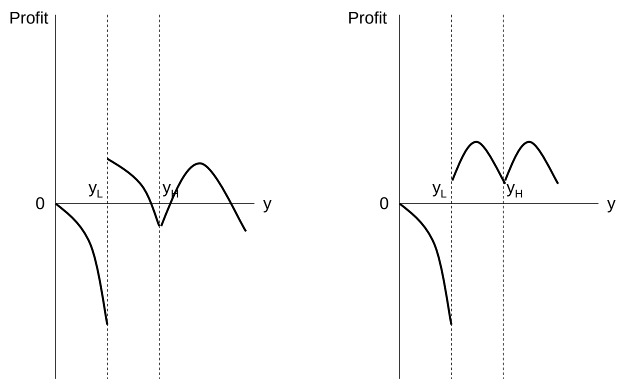
$$y_E(m) = [\frac{\alpha}{w} p_L(m)]^{\frac{\alpha}{1-\alpha}}. \tag{36}$$

This is the case with MC'''' above. The next figure illustrates the profit function in this case.



4. If either $MC(y(m))$ and $MR(y(m))$ cross twice for strictly positive quantities or if they cross once, but $MC(y(m))$ lies above $MR(y(m))$ between $y_L(m)$ and $y_H(m)$, i.e., if $MC(y_H(m)) > \lim_{y(m)\searrow y_L(m)} MR(y(m))$ and $MC(y_H(m)) < \lim_{y(m)\searrow y_H(m)} MR(y(m))$, then there exist two positive local maximizers, one in which firm m sells exclusively on the local market, choosing either $y_M(m)$ or $y_L(m)$, and one in which it also exports, choosing $y_E(m)$. Its choice in this case cannot be determined *a priori* at the present stage, but has to be determined in equilibrium by comparison of the two local maxima.

   This is the case with MC''' above. The next figure illustrates two possible profit functions in this case.



Explicit calculation allows us to find the thresholds mentioned in Lemma 1. Let us define

$$
\begin{aligned}
w_0(m) &\equiv p_H(m)^{\frac{\alpha+\sigma(1-\alpha)}{\alpha}}[v(m)^{\sigma-1}P^{\sigma}y(1)]^{\frac{\alpha-1}{\alpha}}, & (37)\\
\widehat{w_1}(m) &\equiv \alpha[(1+\tau)(1+a)]^{-2\frac{\alpha+\sigma(1-\alpha)}{\alpha}}w_0(m), & (38)\\
\widetilde{w_1}(m) &\equiv \alpha\frac{\sigma-1}{\sigma}w_0(m), & (39)\\
\overline{\tau} &\equiv \frac{1}{1+a}\left(\frac{\sigma}{\sigma-1}\right)^{\frac{\alpha}{2[\alpha+\sigma(1-\alpha)]}}-1. & (40)
\end{aligned}
$$

These thresholds are defined such that

- $\pi(m|y_L(m)) \geq 0 \iff w \leq w_0(m)$,
- $MC(y_L(m)) = \lim_{y(m)\searrow y_L(m)} MR(y(m)) \iff w = \widetilde{w_1}(m)$,
- $MC(y_H(m)) = \lim_{y(m)\nearrow y_H(m)} MR(y(m)) \iff w = \widehat{w_1}(m)$
- $\widetilde{w_1}(m) > \widehat{w_1}(m) \iff \tau > \overline{\tau}$.

Given this, Lemma 1 just amounts to a re-writing of the results obtained above.

It is also easy to show that $w_0(m)$ is greater than both $\widetilde{w_1}(m)$ and $\widehat{w_1}(m)$, that all of them are increasing functions of $v(m)$, and that therefore, at a given w, firms with a very low quality will remain inactive, firms with intermediate quality will produce to serve the domestic market, and firms with a very high quality will also export.

Proof of Proposition 1

In closed economy, there is no competition with the rest of the world, which means that intermediate good producers face a continuous demand with no threshold effects. Then the general equilibrium is easy to derive. From the final good market we know that $p(1) = P$. Equilibrium in the intermediate goods market ($y(m) = x(m)$, $m = L, H$, according to (11)) and in the labor market ($L^d = 1$, according to (16)) then yield $y(1)$ as a function of P and of the prices of low and high quality intermediate goods, $p(L)$ and $p(H)$, respectively. The definition of the price index P in (14) then yields $y(1)$ as a function of the prices of intermediate goods alone. Such prices are determined by $p(m) = p_M(m)$, $m = L, H$, according to (35). This yields the wage rate w as a function of $p(L)$ and $p(H)$. Substituting for w, we can therefore express $p(H)$, w, P and $y(1)$, $y(L)$, $y(H)$, all as functions of $p(L)$ alone. In particular, we find that the real part of the equilibrium is independent from the nominal part: defining a variable $A \equiv \left\{ u \left[\frac{v(L)}{v(H)}\right]^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} + (1-u) \right\}$, which is decreasing in u and increasing in the domestic 'bad' to 'good' quality ratio $\frac{v(L)}{v(H)}$, we have $y(1) = v(H) A^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}}$, $y(L) = \left[\frac{v(L)}{v(H)}\right]^{\frac{\alpha(\sigma-1)}{\alpha+\sigma(1-\alpha)}} A^{-\alpha}$ and $y(H) = A^{-\alpha}$. The nominal part is defined by $p(H) = \left[\frac{v(L)}{v(H)}\right]^{\frac{(\alpha-1)(\sigma-1)}{\alpha+\sigma(1-\alpha)}} p(L)$, $w = \frac{\alpha(\sigma-1)}{\sigma} A^{1-\alpha} \left[\frac{v(L)}{v(H)}\right]^{\frac{(\alpha-1)(\sigma-1)}{\alpha+\sigma(1-\alpha)}} p(L)$ and $p(1) = P = A^{\frac{1}{1-\sigma}} \left[\frac{v(L)}{v(H)}\right]^{\frac{(\alpha-1)(\sigma-1)}{\alpha+\sigma(1-\alpha)}} \frac{p(L)}{v(H)}$. Taking one good as numeraire, for instance setting $p(1) = 1$, completes the characterization of the unique general equilibrium.

Appendix B: Existence and uniqueness of symmetric equilibria

In this appendix we study existence and uniqueness of the six structurally different potential symmetric equilibria of the open economy model, summarized by the following table. It is easy to show that cannot be any other symmetric equilibria.

	Type of symmetric eq.	**'Good firms'**	**'Bad firms'**
EE	**Export and export**	sell locally and export	sell locally and export
ES	**Export and survive**	sell locally and export	just sell locally
ED	**Export and die**	sell locally and export	stay closed
SS	**Survive and survive**	just sell locally	just sell locally
SD	**Survive and die**	just sell locally	stay closed
DD	**Die and die**	stay closed	stay closed

We first show that no EE and ES equilibria exist, because their high demand for labor would push up wages too much to allow even 'good' firms to profitably export. We next show that for some parameter values, an ED equilibrium exists, and that, if it exists, it is unique. In other words, in a symmetric equilibrium of this economy, exporting is only compatible with the existence of some inactive local firm. We then turn to SS equilibria and we prove existence for some parameter values and, in general, multiplicity of such equilibria. As far as SD equilibria are concerned, although we could not prove analytically that they do not exist, in repeated numerical exercises we did not find any parameter constellation for which they indeed exist. Notice in any case that such equilibria are not very interesting from an economic point of view. Finally, we prove that no DD equilibrium exists, because there would be excess supply of labor. In general, we find that for some parameter values, a symmetric equilibrium may either fail to exist, it may exist and be unique, or there may exist multiple equilibria.

As it was to be expected, the sharp international competition implied by the perfect substitutability of intermediate goods at different quality levels, combined with the the presence of heterogeneous local producers, significantly complicates the symmetric general equilibrium analysis of the model. While for the sake of analytical rigor we go through all the possibilities, our main interest is not in the issues of existence and uniqueness, but rather in the policy implications of the model from a dynamic perspective. Once we take a policy-oriented perspective, we can show that the issue of existence and multiplicity is not such a dramatic one for our model.

First of all, for a sufficiently high level of tariff protection, an SS equilibrium always exists, such that all firms produce exactly the same quantities as under autarky ('autarky-like equilibrium'). As a consequence, all intermediate goods $m \in [0, 1)$ are produced in quantity $y_M(m)$ and sold at $p_M(m)$, i.e., at their closed economy monopoly markup. Yet for lower tariffs there may be different SS equilibria, in which international competition forces either some or all of intermediate good producers to sell at the lower, limit prices $p_H(m)$, if they want to sell at all. In other words, intermediate firms are forced to increase production from $y_M(m)$ to $y_L(m)$, because otherwise their market price would be too high for anybody to buy from them. To keep the exposition simple, and without any relevant implication in terms of results, we disregard the mixed cases in which some firms m produce $y_M(m)$ and other ones m' produce $y_L(m')$, for $m, m' \in L, H,\ m \neq m'$, and just focus on the two cases in which either all firms produce the same quantities as under autarky or all of them increase production to sell at the limit price.

Before turning to the formal analysis, let us discuss a bit deeper the case of SS equilibria. Since in an SS equilibrium there is no international trade, taking time 0 foreign consumption as a numeraire opens the possibility that, for some values of the parameters (in particular, of the tariff), there is an entire range of one price compatible with equilibrium. To understand this, it may be useful to recall that in the analysis of autarky we have expressed equilibrium as a function of $p(L)$. Under autarky, taking a numeraire was sufficient to uniquely determine all prices. Yet for an open economy, when the numeraire is taken in the foreign economy, and there is no international trade, one price in the domestic SS equilibrium remains analytically undetermined. Every value of that price then defines a potential SS equilibrium, and one has to check whether this is indeed an equilibrium or not, i.e., one has to make sure that nobody has an incentive to deviate. We perform this check and find that there may exist a continuum of SS equilibria, corresponding to the values of the undetermined price within a given interval. We show that this is true both for the SS equilibrium with autarkic production quantities and for that with higher quantities and limit pricing. We further show that in both cases any equilibrium in the corresponding range displays the same production quantities and consumption levels, independently of the particular price chosen in the equilibrium interval. Therefore, given that our focus is on production and consumption patterns, in our numerical simulations we resolve this multiplicity issue by picking up one specific value for the undetermined price. For mathematical convenience, we take the undetermined price to be $p(L)$ in the former case and w in the latter case and, from the respective intervals where SS equilibria exist, we pick up the mean value of $p(L)$ and the highest value of w. While this is clearly arbitrary, it is useful to stress once again that it has no consequences on the determination of production and consumption patterns, which is what we are interested in.

Let us now turn to the formal analysis of the various cases. As anticipated, the discontinuities and non convexities of the model force us to prove existence in two steps: first, we provide an analytical characterization of a candidate symmetric equilibrium of a given type, by assuming that every agent in the economy behaves in a specific way and by imposing that, given this, all markets clear; second, we study the conditions under which the candidate equilibrium is indeed an equilibrium, i.e., the conditions under which nobody wants to deviate. This second step amounts to checking whether the optimality conditions spelled out in Lemma 1 are satisfied in the candidate equilibrium.

Lemma 2 ***(non existence of 'export and export' equilibria)*** *There does not exist any symmetric equilibrium such that every intermediate good producer both serves the domestic market and exports.*

Proof Suppose there exists a symmetric equilibrium such that both types of firms, besides serving the local market, also export. They would produce $y(m) = \left[\frac{\alpha}{w}p_L(m)\right]^{\frac{\alpha}{1-\alpha}}$ and sell it at $p(m) = pL(m)$, for $m = L, H$.

Labor market equilibrium $L^d = u\left[\frac{\alpha}{w}p_L(L)\right]^{\frac{1}{1-\alpha}} + (1-u)\left[\frac{\alpha}{w}p_L(H)\right]^{\frac{1}{1-\alpha}} = 1$ would then determine the wage rate $w = \alpha\left[up_L(L)^{\frac{1}{1-\alpha}} + (1-u)p_L(H)^{\frac{1}{1-\alpha}}\right]^{1-\alpha}$. Plugging w into the expressions for $y(L)$ and $y(H)$ yields these variables as functions of the parameters only.

Observing that $P = [(1+a)(1+\tau)]^{-1} = p(1)$, it is then immediate to calculate intermediate goods producers' profits and add them to the aggregate wages to derive nominal national income $E = w + u\pi(L) + (1-u)\pi(H) = \frac{w}{\alpha}$.

Equilibrium in the final good market then yields

$y(1) = \left[up_L(L)^{\frac{1}{1-\alpha}} + (1-u)p_L(H)^{\frac{1}{1-\alpha}}\right]^{1-\alpha}[(1+a)(1+\tau)]$.

This immediately yields a contradiction since, given these values, it is immediate to prove that intermediate firms' production is entirely absorbed by domestic demand, so that, contrary to the hypothesis, there are no exports. ■

Lemma 3 ***(non existence of 'export and survive' equilibria)*** *There does not exist any symmetric equilibrium such that high quality firms both serve the domestic market and export, and low quality firms just serve the domestic market.*

Proof Suppose an ES equilibrium exists. Advanced firms sell at $p_L(H)$ their production, which is

$$y(H) = \left[\frac{\alpha}{w} p_L(H)\right]^{\frac{\alpha}{1-\alpha}} \tag{41}$$

From labor market equilibrium ($L^d = uy(L)^{\frac{1}{\alpha}} + (1-u)\left[\frac{\alpha}{w} p_L(H)\right]^{\frac{1}{1-\alpha}} = 1$), we obtain $y(L) = \left\{\frac{1}{u}\left[1-(1-u)\left(\frac{\alpha}{w}p_L(H)\right)^{\frac{1}{1-\alpha}}\right]\right\}^{\alpha}$.

As we know from (11) that $y(L) = p(L)^{-\sigma} v(L)^{\sigma-1} P^{\sigma} y(1)$ we obtain the following condition on $p(L)$:

$$p(L) = v(L)^{\frac{\sigma-1}{\sigma}} P y(1)^{\frac{1}{\sigma}} \left\{\frac{1}{u}\left[1-(1-u)\left(\frac{\alpha}{w}p_L(H)\right)^{\frac{1}{(1-\alpha)}}\right]\right\}^{-\frac{\alpha}{\sigma}} \tag{42}$$

We can now compute

$$P = \left\{1 - u\left[\frac{y(1)}{v(L)}\right]^{\frac{1-\sigma}{\sigma}} \left[\frac{1}{u} - \frac{1-u}{u}\left(\frac{\alpha}{w}p_L(H)\right)^{\frac{1}{1-\alpha}}\right]^{\frac{\alpha(\sigma-1)}{\sigma}}\right\}^{\frac{1}{\sigma-1}} \frac{(1-u)^{\frac{1}{1-\sigma}}}{[(1+a)(1+\tau)]} \tag{43}$$

Let us define $A \equiv \frac{1}{u} - \frac{1-u}{u}\left[\frac{\alpha}{w}p_L(H)\right]^{\frac{1}{1-\alpha}}$ and $B \equiv y(1)^{\frac{\sigma-1}{\sigma}}$ and therefore:

$$P = \left\{\frac{B - uA^{\frac{\alpha(\sigma-1)}{\sigma}} v(L)^{\frac{\sigma-1}{\sigma}}}{B}\right\}^{\frac{1}{\sigma-1}} \frac{(1-u)^{\frac{1}{1-\sigma}}}{[(1+a)(1+\tau)]} \tag{44}$$

$$y(L) = A^{\alpha} \tag{45}$$

We have to compute now $E = w + u\pi(L) + (1-u)\pi(H)$.
$\pi(L) = p(L)y(L) - wy(L)^{\frac{1}{\alpha}}$.
After some algebra, we obtain
$\pi(L) = \frac{(1-u)^{\frac{1}{1-\sigma}} y(1)}{[(1+a)(1+\tau)]} A^{\alpha}\left[\frac{y(1)}{v(L)}\right]^{-1}\left\{BA^{\frac{\alpha(1-\sigma)}{\sigma}} v(L)^{\frac{1-\sigma}{\sigma}} - u\right\}^{\frac{1}{\sigma-1}} - wA$.
Similarly for H firms, we obtain
$\pi(H) = p_L(H)y(H) - wy(H)^{\frac{1}{\alpha}} = \alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)p_L(H)^{\frac{1}{1-\alpha}} w^{\frac{\alpha}{\alpha-1}}$.
Therefore

$$E = w + uA^{\frac{\alpha(\sigma-1)}{\sigma}} v(L)^{\frac{\sigma-1}{\sigma}} y(1)^{\frac{1}{\sigma}} P - uwA + (1-u)\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)p_L(H)^{\frac{1}{1-\alpha}} w^{\frac{\alpha}{\alpha-1}} \tag{46}$$

Noticing that $y(1)P = E$, we obtain:

$$\begin{aligned} y(1) &= \left\{ \left[w(1-uA) + (1-u)\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)p_L(H)^{\frac{1}{1-\alpha}} w^{\frac{\alpha}{\alpha-1}} \right]^{\frac{\sigma-1}{\sigma}} \cdot \right. \\ & \left. \cdot \left[(1+a)(1+\tau)\right]^{\frac{\sigma-1}{\sigma}} (1-u)^{\frac{1}{\sigma}} + u \left[A^\alpha v(L)\right]^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} \end{aligned} \tag{47}$$

We now have all variables as a function of w.

Backward firms may produce either $y_M(L)$ or $y_L(L)$, and sell it at $p_M(L)$ or $p_H(L)$, respectively. We then have two subcases:

1. $y(L) = y_M(L)$

   Equilibrium on the input sector implies that backward firms' supply (equation 45) equals local demand for their products (obtained by plugging equations (44) and (45) in (11)). This condition implies:

$$\begin{aligned} A^\alpha &= \left[\frac{\sigma}{(\sigma-1)} \frac{w}{\alpha} \right]^{-\frac{\alpha\sigma}{\alpha+\sigma(1-\alpha)}} \left\{ v(L)^{\sigma-1} \left[\frac{B - uA^{\frac{\alpha(\sigma-1)}{\sigma}} v(L)^{\frac{\sigma-1}{\sigma}}}{B} \right]^{\frac{\sigma}{\sigma-1}} \cdot \right. \\ & \left. \cdot \frac{(1-u)^{\frac{\sigma}{1-\sigma}}}{[(1+a)(1+\tau)]^\sigma} B^{\frac{\sigma}{\sigma-1}} \right\}^{\frac{\alpha}{\alpha+\sigma(1-\alpha)}} \end{aligned} \tag{48}$$

   From this condition we can derive the wage rate.

$$w = \alpha p_L(H) \left\{ u \left[\left(\frac{\sigma-1}{\sigma}\right)^\sigma \left(\frac{v(L)}{v(H)}\right)^{\sigma-1} \right]^{\frac{1}{\alpha+\sigma(1-\alpha)}} + (1-u) \right\}^{1-\alpha} \tag{49}$$

   Using w, we can obtain the following expressions for $y(H)$ and $y(L)$:

$$y(H) = \left\{ u \left[\left(\frac{\sigma-1}{\sigma}\right)^\sigma \left(\frac{v(L)}{v(H)}\right)^{\sigma-1} \right]^{\frac{1}{\alpha+\sigma(1-\alpha)}} + (1-u) \right\}^{-\alpha} \tag{50}$$

$$y(L) = \left\{ \frac{1}{u} - \frac{1-u}{u} \left[u \left(\left(\frac{\sigma-1}{\sigma}\right)^\sigma \left(\frac{v(L)}{v(H)}\right)^{\sigma-1} \right)^{\frac{1}{\alpha+\sigma(1-\alpha)}} + (1-u) \right]^{-1} \right\}^{\alpha} \tag{51}$$

   and compute $y(1)$ as follows:

$$y(1) = \left\{ u[y(L)v(L)]^{\frac{\sigma-1}{\sigma}} + (1-u)[y(H)v(H)]^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} \tag{52}$$

We can ask now whether it is optimal for advanced firms to export. From (11) we know that local demand for advanced firms equals

$$x(H) = p(H)^{-\sigma} v(H)^{\sigma-1} P^{\sigma-1} p(1) y(1) \tag{53}$$

Plugging (49), (44) and (52) into (53) leads to a contradiction, since we obtain $x(H) = y(H)$. This means that input supply of advanced firms equals local demand and therefore there are no exports.

2. $y(L) = y_L(L)$

   In this case, backward firms sell their production at the limit price: $p(L) = p_H(L)$. A similar procedure leads to the same contradiction: $x(H) = y(H)$ and therefore under this candidate equilibrium, exporting is not optimal for advanced firms and therefore the candidate is not an equilibrium.

■

Lemma 4 ***(existence and uniqueness of 'export and die' equilibria)*** *For some parameter values there exists a symmetric equilibrium such that high quality firms both serve the domestic market and export, whereas low quality firms stay closed and the corresponding goods are imported. If it exists, such equilibrium is unique and its consumption level is*

$$y(1) = \frac{(1-u)^{1-\alpha} p_L(H)}{P - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma} P^{\sigma}}, \tag{54}$$

where

$$P = \left\{u[(1+a)(1+\tau)]^{1-\sigma} + (1-u)[(1+a)(1+\tau)]^{\sigma-1}\right\}^{\frac{1}{1-\sigma}} \tag{55}$$

Proof Suppose there exists an ED equilibrium. Advanced firms would produce

$$y(H) = [\alpha p_L(H)]^{\frac{\alpha}{1-\alpha}} w^{\frac{\alpha}{\alpha-1}} \tag{56}$$

and sell it at $p_L(H)$.

Labor market equilibrium $L^d = (1-u)y(H)^{\frac{1}{\alpha}} = 1$ yields $w = (1-u)^{1-\alpha} \alpha p_L(H)$.

Equation (55) follows from the fact that backward firms stay closed and the corresponding goods are imported, and therefore their price for the domestic buyer includes both transportation costs and tariff.

Profits are

$$\pi(H) = p_L(H)y(H) - wy(H)^{\frac{1}{\alpha}} = \frac{p_L(H)(1-\alpha)}{(1-u)^{\alpha}} \tag{57}$$

As τ applies to landed imports, aggregate tariff revenue is $T = \tau p^*(1+a)Im$ where $Im = uP^{\sigma} y(1)[(1+a)(1+\tau)p^*]^{-\sigma}(v^*)^{\sigma-1}$ as stated by equation (13). Having determined $w, \pi(H)$ and T, we can now compute $E = w + (1-u)\pi(H) + T$. Equilibrium in the final good market $E = \frac{y(1)}{P}$ then yields $y(1)$ as stated in equation (54).

This determines a unique candidate equilibrium. Therefore, if such equilibrium indeed exists, uniqueness is trivially proved. Now we have to perform the optimality test to determine under which conditions nobody has incentive to deviate from the candidate equilibrium, that is, when it is indeed an equilibrium.

First, we have to check that backward firms do not want to deviate, that is, they find it optimal to stay inactive. The necessary and sufficient condition for this is $w > w_0(L)$, which holds if and only if

$$(1-u)^{1-\alpha}\alpha p_L(H) > \left[\frac{p_H(L)}{v(L)}\right]^{\frac{\alpha+\sigma(1-\alpha)}{\alpha}} v(L)^{\frac{1}{\alpha}} \left[\frac{(1-u)^{1-\alpha}p_L(H)}{P^{1-\sigma} - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}}\right]^{\frac{\alpha-1}{\alpha}} \tag{58}$$

Defining

$K_5 \equiv \frac{\alpha^\alpha(1-u)^{1-\alpha}}{[(1+a)(1+\tau)]^{1+\alpha+\sigma(1-\alpha)}\{P^{1-\sigma}-u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}\}^{1-\alpha}}$,

some calculations allows to rewrite this condition as

$$w > w_0(L) \iff \frac{v(L)}{v(H)} < K_5 \tag{59}$$

Notice, after some examination, that $K_5 \in (0,1)$. So, in order for backward firms to find it optimal not to produce when advanced firms even export, they must be sufficiently more backward than advanced ones, i.e., there must be a sufficient degree of domestic heterogeneity.

Now we have to check that advanced firms do not want to deviate, i.e., they find it optimal to produce $y_E(H)$. Lemma 1 states that this holds if and only if any of the following the conditions holds.

1. $w < \frac{\sigma-1}{\sigma}\widehat{w_1}(H)$
2. if $w \in \left(\frac{\sigma-1}{\sigma}\widehat{w_1}(H), max\{\widehat{w_1}(H), \widetilde{w_1}(H)\}\right)$ and $w < \widetilde{w_1}(H)$, then $\pi(H \mid y_E(H)) \geq \pi(H \mid y_M(H))$
3. if $w \in \left(\frac{\sigma-1}{\sigma}\widehat{w_1}(H), max\{\widehat{w_1}(H), \widetilde{w_1}(H)\}\right)$ and $w \geq \widetilde{w_1}(H)$, then $\pi(H \mid y_E(H)) \geq \pi(H \mid y_L(H))$.

First observe that it is always the case that $w < \widehat{w_1}(H)$.
Next consider condition $w > \frac{\sigma-1}{\sigma}\widehat{w_1}(H)$. This holds if and only if
$\left(\frac{\sigma}{\sigma-1}\right)^{\frac{\alpha}{1-\alpha}}(1-u)[(1+a)(1+\tau)]^{\sigma-1} > P^{1-\sigma} - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}$.
Defining $K_1 \equiv \frac{[(\frac{\sigma}{\sigma-1})^{\frac{\alpha}{1-\alpha}}-1][(1+a)(1+\tau)]^{2\sigma-1}}{(1+a)+[(\frac{\sigma}{\sigma-1})^{\frac{\alpha}{1-\alpha}}][(1+a)(1+\tau)]^{2\sigma-1}}$, and solving for u, we obtain

$$w > \frac{\sigma-1}{\sigma}\widehat{w_1} \iff u < K_1 \tag{60}$$

Notice that the higher τ, the easier it is to be in this case.

Consider now condition $w < \widetilde{w_1}(H)$. This holds if and only if $(1-u)^{1-\alpha}\alpha p_L(H) < \alpha y_L(H)^{\frac{\alpha-1}{\alpha}} \frac{\sigma-1}{\sigma} p_H(H)$. Some calculations then yield

$$\begin{aligned}
&w < \widetilde{w_1}(H) \Leftrightarrow \\
&u\left\{[(1+a)(1+\tau)]^{2\sigma-1} - \left(\frac{\sigma}{\sigma-1}\right)^{\frac{\alpha}{1-\alpha}} [(1+a)(1+\tau)]^{\frac{\alpha+1}{\alpha-1}} - (1+a)\right\} < \\
&< [(1+a)(1+\tau)]^{2\sigma-1} - \left(\frac{\sigma}{\sigma-1}\right)^{\frac{\alpha}{1-\alpha}} [(1+a)(1+\tau)]^{\frac{\alpha+1}{\alpha-1}}
\end{aligned}$$

Denote $\Delta \equiv [(1+a)(1+\tau)]^{2\sigma-1} - (\frac{\sigma}{\sigma-1})^{\frac{\alpha}{1-\alpha}} [(1+a)(1+\tau)]^{\frac{\alpha+1}{\alpha-1}}$ and $K_2 \equiv \frac{\Delta}{\Delta-(1+\alpha)}$. Notice that:

- if $\Delta \geq (1+a)$, then $w < \widetilde{w_1}(H)$ always holds.
- if $(1+a) > \Delta \geq 0$, then $w < \widetilde{w_1}(H)$ always holds.
- if $\Delta < 0$, then $w < \widetilde{w_1}(H)$ holds if and only if $u > K_2$.

  Defining $K_3 \equiv \frac{1}{1+a}(\frac{\sigma}{\sigma-1})^{\frac{\alpha}{2(\alpha+\sigma-\alpha\sigma)}}$, observe that $\Delta < 0$ if and only if $1+\tau < K_3$

To sum up, if $u < K_1$, and either $1+\tau \geq K_3$ or $u > K_2$, then we have to check $\pi(H \mid y_E(H)) \geq \pi(H \mid y_M(H))$.

If, on the contrary, $u < K_1$, $1+\tau < K_3$ and $u \leq K_2$, then we have to check $\pi(H \mid y_E(H)) \geq \pi(H \mid y_L(H))$.

- Consider first the case $u < K_1$, and either $1+\tau \geq K_3$ or $u > K_2$.

  We can now plug the values of w, P and $y(1)$ of the candidate equilibrium into the expression of $y_M(H) = \left(\frac{\sigma-1}{\sigma}\frac{\alpha}{w}\right)^{\frac{\alpha\sigma}{\alpha+\sigma(1-\alpha)}} \left[v(H)^{\sigma-1}P^{\sigma}y(1)\right]^{\frac{\alpha}{\sigma(1-\alpha)+\alpha}}$, and then plug $y_M(H)$, $p_M(H)$ and w in $\pi(H \mid y_M(H)) = p_M(H)y_M(H) - wy_M(H)^{\frac{1}{\alpha}}$, to obtain

$$\begin{aligned}
\pi(H \mid y_M(H)) \quad = \quad & \left[\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma-1}{\alpha+\sigma(1-\alpha)}} - \alpha\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}}\right] \cdot \\
& \cdot \left\{\frac{v(H)^{\sigma-1}\left[(1-u)^{1-\alpha}p_L(H)\right]^{1+\alpha-\alpha\sigma}}{P^{1-\sigma} - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}}\right\}^{\frac{1}{\alpha+\sigma(1-\alpha)}}
\end{aligned} \tag{61}$$

  Now we only have to find under which conditions $\pi(H \mid y_E(H)) \geq \pi(H \mid y_M(H))$.

  Defining $\Lambda \equiv \left[\frac{\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma-1}{\alpha+\sigma(1-\alpha)}} - \alpha\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}}}{1-\alpha}\right]^{\alpha+\sigma(1-\alpha)}$ and using (57) and (61), we obtain in this case:

$$\pi(H \mid y_E(H)) \geq \pi(H \mid y_M(H)) \iff$$
$$u\{\Lambda - 1 + (1+a)[(1+a)(1+\tau)]^{1-2\sigma}\} \geq \Lambda - 1 \tag{62}$$

Defining $K_4 \equiv \frac{\Lambda-1}{\Lambda-1+(1+a)[(1+a)(1+\tau)]^{1-2\sigma}}$, we can see that there are two possibilities for this condition to be hold:

- If the right hand side is negative, then it always hold.
- If the right hand side is positive, we have to solve (62) for u. Then the condition becomes:

$$\pi(H \mid y_E(H)) \geq \pi(H \mid y_M(H)) \iff u \geq K_4 \tag{63}$$

Observe that the right hand side is positive whenever,

$$\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma-1}{\alpha+\sigma(1-\alpha)}} - \alpha\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}} > 1-\alpha \tag{64}$$

- Consider now the case $u < K_1$, $1+\tau < K_3$ and $u \leq K_2$.

  By using the definition of $y_L(H)$ and plugging (55) and (54), we can get

$$y_L(H) = \frac{[(1+a)(1+\tau)]^{-(\sigma+1)}(1-u)^{1-\alpha}}{P^{1-\sigma} - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}}, \tag{65}$$

  which we can substitute into $\pi(H \mid y_L(H)) = y_L(H)^{\frac{\sigma-1}{\sigma}} v(H)^{\frac{\sigma-1}{\sigma}} Py(1)^{\frac{1}{\sigma}} - wy_L(H)^{\frac{1}{\alpha}}$ to obtain, after defining
  $\Upsilon \equiv P^{1-\sigma} - u\tau(1+a)[(1+a)(1+\tau)]^{-\sigma}$,

$$\begin{aligned}\pi(H \mid y_L(H)) \quad = \quad & \Upsilon^{-\frac{1}{\alpha}}\Big\{\Upsilon^{\frac{1-\alpha}{\alpha}} p_L(H)(1-u)^{1-\alpha}[(1+a)(1+\tau)]^{1-\sigma} + \\ & -(1-u)^{\frac{(1-\alpha)(1+\alpha)}{\alpha}} \alpha p_L(H)[(1+a)(1+\tau)]^{-\frac{\sigma+1}{\alpha}}\Big\}\end{aligned} \tag{66}$$

  Making use of (57) and (66), and defining
  $\Phi \equiv \frac{1-u}{(1-u)[(1+a)(1+\tau)]^{2\sigma-1}+u(1+a)}$, some algebra yields

$$\pi(H \mid y_E(H)) \geq \pi(H \mid y_L(H)) \iff$$
$$[(1+a)(1+\tau)]\Phi - \frac{\alpha}{[(1+a)(1+\tau)]^{\frac{1}{\alpha}}}\Phi^{\frac{1}{\alpha}} \leq 1-\alpha \tag{67}$$

Summing up, a symmetric ED equilibrium exist (and it is unique), if and only if all of the following conditions are satisfied:

1. If $u < K_1$ and either $1+\tau \geq K_3$ or $u > K_2$, then conditions (64) and $u < K_4$ do *NOT* both hold.

2. If $u < K_1$, $1+\tau < K_3$ and $u \leq K_2$, then condition (67) holds.

3. $\frac{v(L)}{v(H)} < K_5$

Conditions 1. and 2. above grant that advanced firms do not find it profitable to deviate[47]. Condition 3. grants that closed backward firms do not find it profitable to start production.

It is hard to prove analytically that there are parameters for which these conditions are all satisfied, but numerical examples are abundant. For instance, an ED equilibrium exists for the following constellation of parameters: $v^* = 1, v(H) = 1, v(L) = 0.5, u = 0.5, a = 0, \tau = 0, \alpha = 0.9, \sigma = 4$. ■

Lemma 5 ***(existence of 'survive and survive' equilibria)*** *For any parameter constellation, if τ is sufficiently high, then there exist symmetric equilibria such that both high quality and low quality firms are only active on the local market. In such equilibria, each intermediate good producer m can either produce the same quantity as under autarky, $y_M(m)$, or produce the higher quantity $y_L(m)$. If both high quality and low quality firms produce $y_M(m)$, then the consumption level is*

$$y(1) = \left[uv(L)^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} + (1-u)v(H)^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}\right]^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}} \tag{68}$$

If they both produce $y_L(m)$, then the consumption level is

$$y(1) = \left[uv(L)^{-\frac{1}{\alpha}} + (1-u)v(H)^{-\frac{1}{\alpha}}\right]^{-\alpha} \tag{69}$$

Proof Suppose that an SS equilibrium exists. From the final good market we know that $p(1) = P$. Equilibrium in the intermediate goods market ($y(m) = x(m)$, $m = L, H$, according to (11)) and in the labor market ($L^d = 1$, according to (16)) then yield

$$y(1) = P^{-\sigma}\left\{u\left[p(L)^{-\sigma}v(L)^{\sigma-1}\right]^{\frac{1}{\alpha}} + (1-u)\left[p(H)^{-\sigma}v(H)^{\sigma-1}\right]^{\frac{1}{\alpha}}\right\}^{-\alpha}$$

From Lemma 1 it is immediate to see that any intermediate firm m who chooses to sell only to the domestic market, has only two possible optimal choices: it either produces $y_M(m)$ and sells it at $p_M(m)$, or it produces $y_L(m)$ and sells it at $p_H(m)$. Such quantities and prices are defined in equations (34), (35), and, through (11), by $y_L(m) \equiv x(m|p_H(m))$ and (7), respectively.

Since there are two types of intermediate goods producers, we have four possible combinations of their choices. Only for expositional purposes, we restrict attention

[47] Notice that if $u \geq K_1$, then we already know that they cannot have profitable deviations, so no additional conditions are needed

to the two cases in which either $y(L) = y_M(L)$ and $y(H) = y_M(H)$, or $y(L) = y_L(L)$ and $y(H) = y_L(H)$.

Consider first the former case, i.e., $y(L) = y_M(L)$ and $y(H) = y_M(H)$. The definition of the price index P in (14) allows to write $y(1)$ as a function of $p(L)$ and $p(H)$ alone. Then (35) yields the wage rate w as a function of them. Substituting for w, we can therefore express $p(H)$, w, P, $y(L)$, $y(H)$, $y(1)$, all as functions of $p(L)$ alone. In particular, defining a variable $A \equiv u\left[\frac{v(L)}{v(H)}\right]^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} + (1-u)$, which is decreasing in u and increasing in the domestic quality gap $\frac{v(L)}{v(H)}$, we find the following expressions:

$$p(H) = \left[\frac{v(L)}{v(H)}\right]^{\frac{(\sigma-1)(\alpha-1)}{\alpha+\sigma(1-\alpha)}} p(L) \tag{70}$$

$$w = \alpha\frac{\sigma-1}{\sigma}A^{1-\alpha}\left[\frac{v(L)}{v(H)}\right]^{\frac{(\sigma-1)(\alpha-1)}{\alpha+\sigma(1-\alpha)}} p(L) \tag{71}$$

$$P = \frac{A^{\frac{1}{1-\sigma}}}{v(H)}\left[\frac{v(L)}{v(H)}\right]^{\frac{(\sigma-1)(\alpha-1)}{\alpha+\sigma(1-\alpha)}} p(L) \tag{72}$$

$$y(L) = \left[\frac{v(L)}{v(H)}\right]^{\frac{\alpha(\sigma-1)}{\alpha+\sigma(1-\alpha)}} A^{-\alpha} \tag{73}$$

$$y(H) = A^{-\alpha} \tag{74}$$

and $y(1)$ is given by (68), which is the same as (20).

This proves that, if the equilibrium considered in this case exists, then its level of production of both final and intermediate goods is univocally determined, independently of $p(L)$. We now have to make sure that this candidate equilibrium is indeed an equilibrium, in the sense that nobody wants to deviate. This is going to determine a set of values of $p(L)$, for each of which such an equilibrium exists. In principle, this set can either be empty, or be a singletone, or have cardinality higher than one. We find two results: first, for τ sufficiently high this set is not empty. To see this, recall that the autarkic equilibrium always exists. Second, when it is not empty, this set is an interval, that is, there exists an interval of values of $p(L)$, for each of which there exists a symmetric SS equilibrium. Any such equilibrium displays the same production quantities as under autarky. For our purposes, thus, this multiplicity is more apparent than real, and it is due to the fact that we take time 0 foreign consumption as numeraire, but that in equilibrium there is no international trade. This means that the choice of the numeraire is not sufficient to pin down all equilibrium prices, but still the characteristics of the rest of the world influence our small economy, because they determine the range in which no agents wants to deviate. For instance, an SS equilibrium in which production quantities are the same as under autarky exists for the following constellation of parameters: $v^* = 1, v(H) = 1, v(L) = 0.8, u = 0.5, a = 10\%, \alpha = 0.9, \sigma = 4$ and $\tau > 85\%$.

Consider now the second possibility, i.e., $y(L) = y_L(L)$ and $y(H) = y_L(H)$. Intermediate goods prices are $p(L) = p_H(L)$ and $p(H) = p_H(H)$, so that $p(1) = P = (1+a)(1+\tau)$. Then intermediate goods market equilibrium and labor market equilibrium imply that $y(1)$ is given by (69). Knowing this, also $y(L)$ and $y(H)$ are univocally determined. Once again, we have a free price, in this case w. Therefore, each value of w defines a candidate equilibrium, and we have to check for which values of w nobody has an incentive to deviate (so that prices and quantities indeed constitute an equilibrium). In any such equilibrium, production quantities are the same, so that, if multiple such equilibria exist, once again for our purposes multiplicity is more apparent than real. For instance, an SS equilibrium in which both high and low quality firms produce more than under autarky exists for the following constellation of parameters: $v^* = 1, v(H) = 1, v(L) = 0.8, u = 0.5, a = 10\%, \alpha = 0.9, \sigma = 4$ and $\tau > 10\%$. ∎

Since within each of these two kinds of SS equilibrium production quantities do not depend upon the analytically undetermined price, in the numerical simulation we tackle the possible multiplicity problem by arbitrarily choosing the mean $p(L)$ in the equilibrium interval in the first case and the highest w in the equilibrium range in the second case, with no implications for real production quantities. A more serious issue is the possibility that, for some parameter values, both kinds of equilibria exist. We do not resolve this possibility by any ad hoc assumption. Rather, we compare the dynamic implications of different policies, one of which focuses on the lowest tariff that allows survival in equilibrium of both high and low quality firms, be they producing the same quantities as under autarky or higher quantities. Under such minimum SS-compatible tariff, there typically exists only one kind of equilibrium, but for the theoretical possibility that there exist both kinds of SS equilibrium, in the numerical simulation we focus on the autarkic-like one if it exists, and on the other one otherwise.

Lemma 6 ***(non existence of 'survive and die' equilibria)*** *There does not exist any symmetric equilibrium such that high quality firms are only active on the local market and backward firms stay closed.*

Proof In what follows, we spell out necessary and sufficient conditions for SD equilibria to exist. While we do not offer an analytical proof that such conditions imply a contradiction, we have never found parameter values for which SD equilibria exist, despite a careful and systematic numerical exploration of the parameter space.

Assume an SD equilibrium exists. As advanced firms do not export, $y(H) = x(H) = p(H)^{-\sigma} v(H)^{\sigma-1} P^{\sigma} y(1)$. Using equilibrium on the labor market ($L^d = (1-u) y(H)^{\frac{1}{\alpha}} = 1$), we can derive the following equilibrium condition on $p(H)$:

$$p(H) = \left[(1-u)^{\alpha} v(H)^{\sigma-1} P^{\sigma} y(1)\right]^{\frac{1}{\sigma}} \tag{75}$$

Using p(H) and recalling that backward production is replaced by imports, we obtain:

$$P = \left\{u[(1+a)(1+\tau)]^{1-\sigma} + (1-u)[(1-u)^{\alpha}v(H)^{-1}P^{\sigma}y(1)]^{\frac{1-\sigma}{\sigma}}\right\}^{\frac{1}{1-\sigma}}$$

$$= \left\{\frac{u[(1+a)(1+\tau)]^{1-\sigma}}{1-\left[(1-u)^{\alpha+\sigma(1-\alpha)}v(H)^{\sigma-1}y(1)^{1-\sigma}\right]^{\frac{1}{\sigma}}}\right\}^{\frac{1}{1-\sigma}} \tag{76}$$

Since total imports are $M = u\frac{P^{\sigma}}{v^*}y(1)$, we can compute the tariff revenues:

$$T = u\tau(1+a)P^{\sigma}y(1) \tag{77}$$

Using (75) to obtain $y(H) = (1-u)^{-\alpha}$, we find the following expression for profits:

$$\pi(H) = \left[(1-u)^{\alpha(1-\sigma)}v(H)^{\sigma-1}P^{\sigma}y(1)\right]^{\frac{1}{\sigma}} - \frac{w}{(1-u)} \tag{78}$$

We can now plug (77) and (78) in $E = w + (1-u)\pi(H) + T$ to obtain:

$$E = \left[(1-u)^{\alpha+\sigma(1-\alpha)}v(H)^{\sigma-1}P^{\sigma}y(1)\right]^{\frac{1}{\sigma}} + u\tau(1+a)P^{\sigma}y(1) \tag{79}$$

Finally, plugging (76) and (78) in $Py(1) = E$ we obtain:

$$y(1) = v(H)(1-u)^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}}\left\{1-\left[\frac{u^{\frac{1}{\sigma-1}}}{\Gamma}\right]^{\frac{\sigma-1}{\sigma}}\right\}^{\frac{\sigma}{1-\sigma}} \tag{80}$$

where $\Gamma \equiv [(1+a)(1+\tau)] - \tau(1+a)[(1+a)(1+\tau)]^{\sigma}$.

Observe that $\Gamma > u^{\frac{1}{\sigma-1}}$ is a necessary and sufficient condition for $y(1) > 0$. This means that this equilibrium may exist only for sufficiently low values of τ, which push backward firms out of the domestic market.

Given that advanced firms are only active on the domestic market, they can either produce quantity $y_M(H)$ and sell it at price $p_M(H)$, or they can produce $y_L(H)$ and sell it at the limit price $p_H(H)$. We therefore have two cases.

Consider first the case of $y(H) = y_M(H)$. This implies

$$(1-u)^{-\alpha} = \left[\frac{\sigma w}{\alpha(\sigma-1)}\right]^{-\frac{\alpha\sigma}{\alpha+\sigma(1-\alpha)}}\left[v(H)^{\sigma-1}P^{\sigma}y(1)\right]^{\frac{\alpha}{\alpha+\sigma(1-\alpha)}} \tag{81}$$

and therefore

$$w = \frac{\alpha(\sigma-1)}{\sigma}p_H(H)u^{-\frac{1}{\sigma}}(1-u)^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}}\left(\Gamma^{\frac{\sigma-1}{\sigma}} - u^{\frac{1}{\sigma}}\right)^{\frac{1}{1-\sigma}} \tag{82}$$

We now have to check that nobody wants to deviate. For low quality firms, this means $w > w_0(L)$. After some algebra we obtain that this is true whenever:

$$\frac{v(H)}{v(L)} > \left[\frac{\sigma}{\alpha(\sigma-1)}\right]^{\alpha}\left\{\frac{u^{\frac{1}{\sigma}}}{(1-u)^{\frac{1}{\sigma-1}}}\left[\Gamma^{\frac{\sigma-1}{\sigma}} - u^{\frac{1}{\sigma}}\right]^{\frac{1}{\sigma-1}}\right\}^{\alpha+\sigma(1-\alpha)} \tag{83}$$

For high quality firms, we have to investigate the case of $w \in \left(\frac{\sigma-1}{\sigma}\widehat{w_1}(H),\ max\{\widehat{w_1}(H), \widetilde{w_1}(H)\}\right)$. Condition $w > (\frac{\sigma-1}{\sigma})\widehat{w_1}(H)$ holds if and only if

$$\Gamma < \frac{1}{u}\left\{(1-u)[(1+a)(1+\tau)]^{2(\sigma-1)} + u\right\}^{\frac{\sigma}{\sigma-1}} \tag{84}$$

The next step consist of considering $w < max\{\widehat{w_1}(H), \widetilde{w_1}(H)\}$. If $\tau > \overline{\tau}$, then this condition becomes $w < \widetilde{w_1}(H)$ and it holds if and only if

$$\Gamma > \frac{1}{u}\left\{(1-u)^{\frac{\alpha+\sigma(1-\alpha)}{\sigma}} + u\right\}^{\frac{\sigma}{\sigma-1}} \tag{85}$$

Notice that $w < \widetilde{w_1}(H)$ always holds when $\tau \leq \overline{\tau}$. Therefore, provided $\Gamma > u^{\frac{1}{\sigma-1}}$, (83), (84) and (85), there remains to check that, if $w < \widehat{w_1}(H)$, then $\pi(H \mid y_M(H)) \geq \pi(H \mid y_E(H))$.

Condition $w < \widehat{w_1}(H)$ holds if and only if

$$\Gamma > \frac{1}{u}\left\{\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha(\sigma-1)}{\alpha+\sigma(1-\alpha)}}(1-u)[(1+a)(1+\tau)]^{2(\sigma-1)}\right\}^{\frac{\sigma}{\sigma-1}} \tag{86}$$

Noticing that $y_M(H) = (1-u)^{-\alpha}$ and therefore

$$\pi(H \mid y_M(H)) = \frac{(1-u)^{1-\alpha}}{u^{\frac{1}{\sigma}}}p_H(H)\left[(1-u)^{\alpha} - \frac{\alpha(\sigma-1)}{\sigma}\right]\left(\Gamma^{\frac{\sigma-1}{\sigma}} - u^{\frac{1}{\sigma}}\right)^{\frac{1}{1-\sigma}} \tag{87}$$

and observing further that $\pi(H \mid y_E(H)) = w^{\frac{\alpha}{\alpha-1}}p_L(H)^{\frac{1}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)$, which, after replacing w and $p_L(H)$, becomes

$$\begin{aligned}\pi(H \mid y_E(H)) \quad = \quad & \alpha^{\frac{1}{1-\alpha}}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha}{\alpha-1}}(1-\alpha)p_H(H)^{\frac{\alpha}{\alpha-1}}p_L(H)^{\frac{1}{1-\alpha}}\frac{(1-u)^{\frac{\alpha[\alpha+\sigma(1-\alpha)]}{1-[\alpha+\sigma(1-\alpha)]}}}{u^{\frac{\alpha}{\sigma(\alpha-1)}}}\cdot \\ & \cdot\left(\Gamma^{\frac{\sigma-1}{\sigma}} - u^{\frac{1}{\sigma}}\right)^{\frac{\alpha}{[\alpha+\sigma(1-\alpha)]-1}}\end{aligned} \tag{88}$$

we can finally conclude that, if condition (86) holds, then $\pi(H \mid y_M(H)) \geq \pi(H \mid y_E(H))$ holds if and only if

$$\Gamma \leq \frac{1}{u}\left\{(1-u)^{\alpha}\left[\frac{\left(\frac{\sigma-1}{\sigma}\right)^{\alpha}[(1+a)(1+\tau)]^2(1-u)^{1-\alpha}}{\alpha(1-\alpha)^{1-\alpha}}\left((1-u)^{\alpha} - \frac{\alpha(\sigma-1)}{\sigma}\right)^{1-\alpha}\right]^{\sigma-1} + u\right\}^{\frac{\sigma}{\sigma-1}} \tag{89}$$

This concludes the analysis of the first case.

The last step is to examine the second case, that in which $y(H) = y_L(H)$. This holds if and only if $(1-u)^{-\alpha} = p_H(H)^{-\sigma} v(H)^{\sigma-1} P^{\sigma} y(1)$, which after some algebra becomes

$$\Gamma = \frac{1}{u} \tag{90}$$

Since Γ is decreasing in τ and for $\tau = 0$ we have $\Gamma = 1 + a$, where $a \in [0, 1)$ is small, a sufficient condition for (90) NOT to hold is $\frac{1}{u} > 1 + a$, which we assume. Under this assumption, there may exist only the first type of SD equilibrium, that with $y(H) = y_M(H)$. ■

Lemma 7 ***(non existence of 'die and die' equilibria)*** *There cannot exist any symmetric equilibrium such that both high and low quality firms are inactive.*

Proof Trivially, if such an equilibrium existed, domestic labor demand would be zero, but then the domestic labor market would not clear. ■

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