Endogenous market structure and the growth and welfare effects of economic integration

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Abstract

I study the growth and welfare effects of integration in a world economy populated by global oligopolists. For economies that move from autarky to trade, I show that growth and welfare rise because exit of domestic firms is more than compensated by entry of foreign firms so that integration generates a larger, more competitive market where firms have access to a larger body of technological spillovers that support faster growth. The effects of a gradual reduction of barriers to trade – a global reduction in tariffs – are different because economies start out from a situation where all firms already serve all markets. In this case, integration brings about a reduction of the global number of firms so that the variety of consumption goods and the diversity of innovation paths fall. The surviving firms, on the other hand, are larger and exploit static and dynamic economies of scale to a larger degree. These homogeneization and rationalization effects work in opposite directions. Under plausible conditions, the rationalization effect dominates and growth and welfare rise.

Keywords: Market Structure, Growth, R&D, Integration.

JEL Classification Numbers: E10, L16, O31, O40

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1 Introduction

In the last fifty years the world has become more integrated as institutional and technological changes have lowered barriers to the mobility of goods, capital and people. This process of globalization affects individual economies through several mechanisms. A very powerful one is industrial restructuring, that is, the change in market structure that occurs as a result of entry/exit of firms. In this paper, I discuss a model where industrial restructuring entails exit of domestic firms and ask whether such a change in market structure is beneficial for growth and welfare.¹

For economies that move from autarky to trade – free or restricted by tariffs – I show that integration raises growth and welfare because exit of domestic firms is more than compensated by entry of foreign firms. In other words, the fact that domestic consumers and producers gain access to foreign goods and knowledge means that integration generates a larger, more competitive market where firms have access to a more diverse body of technological spillovers that supports faster growth. The growth effect is larger the less competitive the economy is before integration, while it is negligible for economies that are very competitive to begin with. The effects of a gradual reduction of barriers to trade – a global reduction in tariffs – are different because economies start out from a situation where all firms already serve all markets. Hence, the reduction of barriers to trade makes all markets more competitive, in the sense that in each country domestic producers are less protected, and thereby triggers a reduction in the global number of firms. In other words, in each country consumers see a reduction of the variety of available goods and producers see a reduction of the diversity of spillovers sources. In this case, there is a tension between internal and external increasing returns. The reduction of the global number of firms means that the variety of consumption goods and the diversity of innovation paths fall. I call this the homogenization effect. On the other hand, the surviving firms are larger and exploit static and dynamic economies of scale to a larger degree. I call this the rationalization effect. A global reduction in tariffs raises growth and welfare if the rationalization effect dominates.

Two aspects of my analysis are worth emphasizing. First, the notion that openness to foreign competition drives domestic firms out of business is accepted by most people. What is not often accepted, however, is that the benefits dominate the costs. An exception is the rationalization argument

¹For a recent exposition of the view that this type of work is necessary to better understand the interactions of technology and trade, see Baldwin and Forslid (1998).
due to Eastman and Stykolt (1960), and formalized by Dixit and Norman (1980) and Horstman and Markusen (1986), that protection leads to excessive entry and thus prevents firms from achieving an efficient size. Horstman and Markusen wrote partially in response to Venables (1985), who argued that protection can raise national welfare in the context of a homogeneous good model where markets are segmented, and showed that his results depended crucially on the assumption of segmented markets. Venables (1987), in turn, pointed out that the difference between segmented and integrated markets is irrelevant in a differentiated products model and showed that the benefits from protection stem from the fact that it raises the share of the market for differentiated goods that domestic firms capture. This paper provides a generalization of these arguments to a framework where the number of firms and firm size— which are jointly determined and thus interdependent— affect economic growth. Moreover, it looks at the general equilibrium effects for the global economy of multilateral actions— like the global reduction in tariffs due to the GATT— as opposed to focusing on unilateral trade policy. The framework takes into account several features of real-world industry and does not produce counterfactual predictions, like a linear scale effect, that make previous analyses of the growth effects of integration not convincing. Moreover, it sheds light on the conditions under which protection is or is not beneficial and thus clarifies important issues in the debate on the “new protectionism” that trade models based on increasing returns seem to underpin intellectually.

Second, the effects of incremental liberalization are different from those of a move from autarky to free trade. According to Baldwin and Forslid (1999, 2000), this is a property shared by most trade models based on imperfect competition that stems from the fact that incremental trade liberalization has non-linear effects (see also Rivera-Batiz and Romer 1991b). My results point out that, in fact, the relation between protection and the number of goods is not just non-linear but discontinuous in that autarky is not the limit of the trade model for a tariff that goes to infinity. This discontinuity is embedded in models of product variety because these models

2Rivera-Batiz and Romer (1991a), for example, base their analysis on first-generation models of endogenous growth where increasing returns apply at the aggregate level. This property implies that the economy’s growth rate increases linearly with its labor endowment (population size). Recent research has shown that this linear scale effect is empirically false (see, e.g., Backus, Kehoe and Kehoe 1992, Jones 1995, Dinopoulos and Thompson 1999), it is not an unavoidable feature of endogenous growth models and, more importantly, is produced by extreme assumptions on the diffusion and application of knowledge that are not convincing (for recent reviews of this line of work, see Jones 1999, Aghion and Howitt 1998, and Peretto and Smulders 1999).
by construction let consumers have access to all goods. This means that
a reduction of trade frictions affects the quantity of each foreign good that
domestic consumers buy but does not affect the wedge between the number
of goods produced domestically and the number of goods that are available
to domestic consumers. A comparison of autarky to trade, in contrast, fo-
cuses by construction on the wedge between goods produced domestically
and goods available to consumers.

This paper studies issues that are notoriously complex. To keep the anal-
ysis tractable, I focus on the effects of integration among identical countries.
As a result, I work with a model of intra-industry trade in the tradition of
Helpman and Krugman (1985) and ignore the effects that derive from com-
parative advantage when technologies, preferences, and endowments differ. \(^3\)
Specifically, I model a world economy characterized by global oligopolists
that produce differentiated goods, engage in worldwide Bertrand price com-
petition and establish in-house R&D facilities to produce, over time, a con-
stant flow of incremental, cost-reducing innovations. Welfare in the typical
country depends on the level and growth of consumption and on the variety
of consumption goods. The effects of integration depend on what changes
in market structure it generates in the global economy. \(^4\)

The seminal work on the topic is that of Rivera-Batiz and Romer (1991a,
1991b). Their analysis is based on first-generation models of endogenous
growth whereby the benefits of integration stem from an implausibly large
scale effect. My model does not suffer from this flaw. In fact, with an
endogenous number of firms, it is almost “natural” to predict that larger

\(^3\)One can look at industrial restructuring in two ways. In two-sector models of inter-
industry trade, entry/exit is driven by a specialization effect: as a country specializes
in one sector, there is entry of firms to that sector and exit from the other sector. In
one-sector models of intra-industry trade, in contrast, entry/exit is driven purely by a
scale effect: as a country trades with another, the market becomes larger and induces
entry/exit of firms. Specialization and scale effects are not independent. In two-sector
models of inter-industry trade, specialization affects market structure within each sector
precisely because it changes the relative and absolute size of the two sectors and thereby
triggers entry/exit within each sector. In one-sector models of intra-industry trade, the
inter-industry specialization effect is absent and what is left is the pure scale effect based
on market size.

\(^4\)Like in all models of market structure and trade based on increasing returns, the
pattern of intra-industry specialization (which country produces which good) is not deter-
mined (see, e.g., Helpman and Krugman 1985). However, this pattern is irrelevant for the
main results of the paper because all product lines are identical and preferences are sym-
metric over all goods. Since the aggregate performance of a country does not depend on
its specialization, specifying some process that determines which country produces which
good would only complicate the presentation without adding insight.
economies do not grow faster but pursue a larger variety of innovation paths. Moreover, I provide results on welfare, which they ignore. Finally, I predict a monotonically decreasing or hump-shaped relation between protection and worldwide growth whereas they predict a U-shaped one.

Recent papers that are more directly comparable to the present one are Smulders and van de Klundert (1995), Wacziarg (1997), Baldwin and Forslid (1999, 2000), and Piermartini (1999). Smulders and van de Klundert do not focus on the effects of integration but offer some conclusions based on a simple extrapolation of a closed-economy model. Wacziarg has no endogenous growth. His analysis therefore cannot offer insights on the growth effects of integration beyond the transitional effects due to capital accumulation. Moreover, his focus on a small, open economy eliminates the global general equilibrium effects that drive my results. Baldwin and Forslid introduce incremental trade liberalization and generalize the analysis of Rivera-Batiz and Romer (1991b) by introducing procompetitive effects in the research sector captured by an exogenous parameter. The main differences between their work and what I do are that they have atomistic research firms, and thus rule out procompetitive effects that stem from endogenous mark-ups that vary with the number of firms, and work with a straightforward extension of first-generation endogenous growth models that exhibits the linear scale effect that I criticized above. Of all these papers, Piermartini comes closer to my work. She considers inter-industry and intra-industry effects of incremental integration due to a reduction of iceberg transport costs. The main differences are that I work with a simpler model, compare a reduction in tariffs to a move from autarky to trade, and provide a global (as opposed to local) characterization of the effects of tariffs.

These papers are complementary to the present one. The general lesson of this line of work is that when the interactions generated by the endogenous market structure are taken into account, the evaluation of the growth and welfare effects of integration is qualitatively different from what one finds in the context of traditional exogenous growth models or first-generation endogenous growth models.

I proceed as follows. In section 2, I present the basic closed-economy model that in section 3 I generalize to the case of trade restricted by ad-valorem import tariffs. In section 4, I show how a move from autarky to free trade improves growth and welfare. In section 5, I study the effects of a global reduction in tariffs. In Section 6, I compare the two exercises and discuss the differences in the results that they yield.
2 The basics: preferences, technology and equilibrium concept

Consider an economy with a fixed population, \( L \), of identical consumers each endowed with one unit of labor. I abstract from labor-leisure decisions so that labor supply is \( L \). Consumers have symmetric preferences over differentiated goods supplied by oligopolistic manufacturing firms. Each firm supplies one good. Price-setting firms maximize the present value of profits subject to their demand schedules. This guarantees that supply equals demand in the goods market. Labor and capital market clearing determine the economy’s general equilibrium.

2.1 Preferences

The typical consumer maximizes lifetime utility

\[
U(t) = \int_t^\infty e^{-\rho(\tau-t)} \log C(\tau) d\tau, \quad \rho > 0, \tag{1}
\]

subject to the intertemporal budget constraint that the present discounted value of expenditure cannot be greater than the present discounted value of labor income plus initial wealth,

\[
\int_t^\infty e^{-\int_t^\tau r(s) ds} E(\tau) d\tau \leq \int_t^\infty e^{-\int_t^\tau r(s) ds} W(\tau) d\tau + B(t),
\]

where \( \rho \) is the individual discount rate, \( E \) is per capita consumption expenditure, \( B \) is the individual’s assets holding, and \( W \equiv 1 \) is the wage rate, which I take as the numeraire.\(^5\) \( C \) is a consumption index defined as

\[
C = \left[ \sum_{i=1}^{N} C_i^{1/\epsilon} \right]^{\epsilon-1}, \quad \epsilon > 1, \tag{2}
\]

where \( \epsilon \) is the elasticity of product substitution, \( C_i \) is the consumer’s purchase of each differentiated good, and \( N \) is the number of goods.

As is well known, in this framework consumers set

\[
\frac{\dot{E}}{E} = r - \rho \tag{3}
\]

\(^5\) The model can be solved using a standard utility function with constant intertemporal elasticity of substitution. Restricting attention to logarithmic utility, however, simplifies the analysis.
and, taking as given this time-path of expenditure, maximize (2) subject to
\[ E = \sum_{i=1}^{N} P_i C_i, \]
determining
\[ X_i = LE \frac{P_i^{1-\epsilon}}{\sum_{j=1}^{N} P_j^{1-\epsilon}}, \]  
where \( X_i = LC_i \).

### 2.2 Technology

Each firm produces output with the technology
\[ X_i = Z_i^\theta (LX_i - \phi), \quad \phi > 0, \quad 0 < \theta < 1, \]  
where \( X_i \) is the firm’s output and \( LX_i \) is the firm’s labor employment in production. There are fixed (and sunk) overhead costs \( \phi \). The firm undertakes R&D in order to accumulate cost-reducing innovations that are patented. \( Z_i \) is the firm’s patent stock. Technological opportunity conditions are described by two functions. The function \( Z_i^\theta \) states that labor productivity rises with the accumulated patent stock. The function
\[ \dot{Z}_i = L Z_i K_i, \quad K_i = Z_i + \sum_{j \neq i}^{N} \frac{\gamma}{1 + \delta (N - 1)} Z_j, \quad 0 \leq \gamma, \delta \leq 1, \]  
states that the firm generates \( \dot{Z}_i \) new patents in the interval of time \( dt \) by allocating \( L Z_i \) units of labor to R&D. Patents contain knowledge that is not innovation-specific and is not appropriable. This implies that a firm’s R&D produces knowledge that can be exploited by other firms. The parameter \( \gamma \) determines the fraction of knowledge that becomes public. The productivity of labor in R&D, \( K_i \), is a weighted average of the firm’s own knowledge and spillovers from the other firms. \( N \) is the number of firms, which is determined endogenously by the equilibrium conditions of the industry.

(6) exhibits constant returns to scale to knowledge that sustain constant endogenous growth in steady state. Spillovers imply increasing returns to the number of firms. The degree to which these apply depends on the interaction of knowledge specialization and R&D replication. Firms produce differentiated products and develop specialized technologies. They thus learn from their similarities as well as from their differences in the sense that the knowledge produced by one firm benefits the R&D effort of another firm according to how close they are in technology space and how little they replicate each others’ R&D. I summarize these factors with the assumption
that the weights assigned to spillovers of knowledge from the other firms are symmetric and decreasing in the number of firms. The first is a simplifying assumption that preserves the overall symmetry of the model; the second captures the notion that “idea congestion” increases with the number of firms in the industry.\textsuperscript{6} The parameter $\delta$ determines how quickly congestion sets in and increasing returns to the number of firms vanish. To see this, notice that in symmetric equilibrium

$$\frac{\dot{Z}}{Z} = L_Z \frac{1 + (\gamma + \delta)(N - 1)}{1 + \delta(N - 1)},$$

where firm-level variables without subscripts denote industry averages. This expression exhibits positive, diminishing returns to the number of firms $N$ that are bounded from above.

\subsection*{2.3 Market structure in general equilibrium}

The market equilibrium of the economy sketched above has three building blocks. First, value maximization determines the price and investment strategies of active firms. Next, entry/exit decisions determine the number of active firms. Finally, these two results combined with labor and market clearing conditions determine the general equilibrium of the economy.

The typical firm maximizes the present discounted value of net cash flow,

$$V_i(t) = \int_t^\infty e^{-\int_t^\tau r(s)ds} \Pi_i(\tau) d\tau.$$

Instantaneous profits are

$$\Pi_i = P_i X_i - L_{X_i} - L_{Z_i},$$

where $L_{X_i}$ is total production costs and $L_{Z_i}$ is R&D expenditure. With perfect foresight, $V_i$ is the stock market value of the firm. Peretto (1996, 1998) provides a formal definition of the Nash equilibrium with free entry/exit for this setup. In words, the Nash equilibrium requires that each firm chooses time-paths of price and R&D investment that maximize $V_i$ and that such maximized value be driven to zero by entry/exit. The Nash equilibrium can thus be described as the outcome of the interaction between two relationships. One represents the optimal R&D strategy of firms given the number

\textsuperscript{6} Peretto and Smulders (1999) provide a microfoundation for these assumptions. They construct a model where the spillovers function that I use in the text is obtained as a result of the interaction among firms.
of firms; the other represents the number of firms that the market supports in zero-profit equilibrium given that firms play the optimal R&D strategy. By construction, these relationships incorporate conditions that the capital and labor markets clear.

The advantage of this setup is that it reduces the determination of the economy’s general equilibrium to the determination of the equilibrium of its manufacturing sector and allows me to concentrate on the role of market structure. In the next section, I adapt this structure to a model of international trade where global oligopolists sell differentiated goods in all countries.

3 The trade model with import tariffs

There are $c$ identical countries. Let $N_k$ be the number of domestic firms in country $k$. Let $M = \sum_{k=1}^{c} N_k$ be the global number of firms. All countries charge an ad-valorem tariff $\tau$ on foreign goods. The part of the model that describes producers and consumers does not change with the exception that now the number of goods in (2) and the number of firms in (6) is the global number of firms (domestic and foreign). In other words, the typical consumer in the typical country consumes all available goods while the typical producer draws spillovers from all firms. This turns out to be important.

3.1 Preliminaries

Most of my results depend on the structure of demand and its implications for the pricing behavior of firms. It is useful to emphasize this aspect of the model from the outset. Formally, (2) and (6) are modified as follows:

\[ C_k = \left[ \sum_{i=1}^{N_k} C_{ik}^{c-1} + \sum_{s \neq k} \sum_{i=1}^{N_s} C_{is}^{c-1} \right]^{\frac{c}{c-1}} \]  
\( \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad

The first equation posits that the typical consumer likes all goods symmetrically. The second posits that the firm draws spillovers from the global population of firms and that spillovers from domestic and foreign firms get the same weight.
In country \( k \), consumers maximize (7) subject to

\[
E_k = \sum_{i=1}^{N_k} P_{ik} C_{ik} + \sum_{s \neq k} \sum_{i=1}^{N_s} (1 + \tau) P_{is} C_{is},
\]

where \( C_{ik} \) is consumption of good \( i \) produced in country \( k \), \( C_{is} \) is consumption of good \( i \) imported from country \( s \), \( P_{ik} \) is the price of good \( i \) produced in country \( k \) and \( P_{is} \) is the price of good \( i \) imported from country \( s \). The price index of consumption goods in country \( k \) is

\[
P_k = \left[ \sum_{j=1}^{N_k} P_{jk}^{1-\epsilon} + \sum_{s \neq k} \sum_{j=1}^{N_s} (1 + \tau)^{1-\epsilon} P_{js}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}.
\]

Solving the optimization problem, one finds that consumers demand goods according to the following schedule:

\[
C^D_{ik} = E_k \frac{P_{ik}^{-\epsilon}}{P_k^{1-\epsilon}};
\]

\[
C^F_{ik} = E_k (1 + \tau)^{-\epsilon} \frac{P_{is}^{-\epsilon}}{P_s^{1-\epsilon}}.
\]

The first equation is the demand for good \( i \) when good \( i \) is produced domestically, the second is the demand for good \( i \) when good \( i \) is imported. Using these results, the total demand faced by firm \( i \) in country \( k \) can be written

\[
X_{ik} = X^D_{ik} + X^F_{ik} = LE_k \frac{P_{ik}^{-\epsilon}}{P_k^{1-\epsilon}} + \sum_{s \neq k} LE_s \frac{(1 + \tau)^{-\epsilon} P_{is}^{-\epsilon}}{P_s^{1-\epsilon}}, \quad (9)
\]

where \( X^D_{ik} \) and \( X^F_{ik} \) denote, respectively, the firm’s domestic and foreign sales and \( P_s \) is the price index of consumption goods in country \( s \).

**Lemma 1** The demand schedule (9) yields the following price elasticity of demand for a global price-setting oligopolist:

\[
\xi \equiv \epsilon - (\epsilon - 1) \left( 1 + (1 + \tau)^{1-2\epsilon} \frac{c-1}{c} \right) \frac{c}{1 + (c-1)(1 + \tau)^{1-\epsilon} cN}. \quad (10)
\]
Proof. Define the following two variables:

\[ S_{D}^{ik} \equiv \left( \frac{P_{ik}}{P_{k}} \right)^{1-\epsilon}; \]

\[ S_{F}^{ik} \equiv (1 + \tau)^{1-\epsilon} \left( \frac{P_{ik}}{P_{s}} \right)^{1-\epsilon}. \]

The first is firm \( i \)'s share of its domestic market, the second is firm \( i \)'s share of any foreign market. After a little algebra – and taking into account that because of the tariff firm \( i \) has a different effect on the price index of its home country and the price index of a foreign country – I obtain

\[ \frac{1}{E_{k} H} \frac{\partial X_{ik}}{\partial P_{ik} X_{ik}} = \frac{E_{k} S_{D}^{ik} + \sum_{s \neq k} E_{s} \frac{1}{1+\tau} \left[ \epsilon S_{F}^{ik} - (\epsilon - 1) \left( S_{D}^{ik} \right)^{2} \right]}{E_{k} S_{D}^{ik} + \sum_{s \neq k} E_{s} \frac{1}{1+\tau} S_{F}^{ik}}. \]

Symmetry across countries allows me to write

\[ \xi_{ik} = \epsilon - (\epsilon - 1) \frac{(S_{D}^{ik})^{2} + (S_{F}^{ik})^{2} \frac{\epsilon - 1}{1+\tau}}{S_{D}^{ik} + S_{F}^{ik} \frac{\epsilon - 1}{1+\tau}}. \]

This expression says that the global market power of firm \( i \) is a weighted average of its market power in its domestic market and in all foreign markets in which it operates. Symmetry across firms allows me to write the market shares as:

\[ S_{D} = \frac{c}{1 + (c - 1) (1 + \tau)^{1-\epsilon} cN}; \]

\[ S_{F} = (1 + \tau)^{1-\epsilon} S_{D}. \]

Symmetry across countries also implies \( M = cN \). The price elasticity of demand that results from these expressions is given in (10). Notice that \( \tau = \infty \Rightarrow \xi = \epsilon - (\epsilon - 1) \frac{1}{N} \) and \( \tau = 0 \Rightarrow \xi = \epsilon - (\epsilon - 1) \frac{1}{cN} \).

The expression for the price elasticity of demand summarizes the effect of trade barriers on market competition: it is monotonically decreasing in the tariff, meaning that trade barriers raise the market power of domestic producers in their own market. All my results stem from the effect of the tariff on market power as captured by this elasticity.
3.2 Market structure in the global economy

It is useful to characterize the general equilibrium of the global economy in three steps. First, I solve for the equilibrium number of firms. Next, I evaluate growth at the equilibrium number of firms. Finally, I evaluate welfare.

**Proposition 2** The following equation determines the number of domestic firms in the general equilibrium of the global economy where the global industry is in symmetric Nash equilibrium with free entry/exit, all domestic labor markets clear, and the global capital market clears:

$$
\phi = \frac{L}{N} \frac{1 - \theta [\xi(cN) - 1]}{\xi(cN)} + \frac{\rho}{\alpha(cN)},
$$

(\text{NN}_{\text{trade}})

where the price elasticity of demand $\xi(cN)$ is given by (10) and

$$
\alpha \equiv \frac{1 + (\gamma + \delta)(cN - 1)}{1 + \delta(cN - 1)}
$$

(11)

is the productivity of R&D. The number of domestic firms is monotonically increasing in the tariff.

**Proof.** Since countries are identical, I can normalize the wage in each one and have a common numeraire. Firm $i$ in country $k$ maximizes $V_{ik}$ subject to (5), (8), (9), $Z_{ik}(t) = Z > 0$ (initial knowledge is given), $Z_{js}(\tau)$ for $\tau \geq t$ given for all $j \neq i$ and for all $s$ (the firm takes as given the rivals’ knowledge paths), and $Z_{ik}(\tau) \geq 0$ for $\tau \geq t$ (knowledge accumulation is irreversible). I assume that firms take their R&D productivity, $K_{ik}$, as given; allowing firms to internalize the effect of their own knowledge on their R&D productivity does not change the qualitative results of the paper. Suppose now that firms finance R&D by issuing ownership claims on the flow of profits generated by cost-reducing innovations. Let the market value of such financial assets be $q_{ik}$. A firm is willing to undertake R&D if the value of the innovation is equal to its cost,

$$
q_{ik} = \frac{1}{K_{ik}} \iff L_{Z_{ik}} > 0.
$$

(12)

Since the innovation is implemented in-house, its benefits are determined by the marginal profit it generates. Thus, the return to the innovation must satisfy the arbitrage condition

$$
r = \frac{\partial \Pi_{ik}}{\partial Z_{ik}} \frac{1}{q_{ik}} + \frac{\dot{q}_{ik}}{q_{ik}}.
$$

(13)
Using (5) and the demand curve (9), the firm’s profit is

$$\Pi_{ik} = \left( P_{ik} - Z_{ik}^{-\theta} \right) \left[ LE_k \frac{P_{ik}^{-\epsilon}}{P_k^{1-\epsilon}} + \sum_{s \neq k}^{c} LE_s \frac{(1 + \tau)^{-\epsilon} P_{ik}^{-\epsilon}}{P_s^{1-\epsilon}} \right] - L Z_{ik} - \phi.$$ 

Hence,

$$\frac{\partial \Pi_{ik}}{\partial Z_{ik}} = \theta Z_{ik}^{-\theta-1} \left[ LE_k \frac{P_{ik}^{-\epsilon}}{P_k^{1-\epsilon}} + \sum_{s \neq k}^{c} LE_s \frac{(1 + \tau)^{-\epsilon} P_{ik}^{-\epsilon}}{P_s^{1-\epsilon}} \right].$$

This expression must be evaluated at the optimal pricing strategy. This is the mark-up rule

$$P_{ik} = \frac{\xi_{ik}}{\xi_{ik} - 1} Z_{ik}^{-\theta}, \quad (14)$$

where $\xi_{ik}$ is the price elasticity of demand that the firm faces. Solving (14) for $Z_{ik}^{-\theta}$ and substituting into marginal profit, I get

$$\frac{\partial \Pi_{i}}{\partial Z_{i}} = \frac{\theta (\xi_{ik} - 1)}{\xi_{ik} Z_{ik}} \left[ LE_k \frac{P_{ik}^{1-\epsilon}}{P_k^{1-\epsilon}} + \sum_{s \neq k}^{c} LE_s \frac{(1 + \tau)^{1-\epsilon} P_{ik}^{1-\epsilon}}{P_s^{1-\epsilon}} \frac{1}{1 + \tau} \right].$$

Taking logs and time derivatives of (12), substituting into (13) and rearranging terms yields

$$r = \frac{\theta (\xi_{ik} - 1)}{\xi_{ik}} \left[ LE_k \frac{P_{ik}^{1-\epsilon}}{P_k^{1-\epsilon}} + \sum_{s \neq k}^{c} LE_s \frac{(1 + \tau)^{1-\epsilon} P_{ik}^{1-\epsilon}}{P_s^{1-\epsilon}} \frac{1}{1 + \tau} \right] \frac{K_{ik}}{Z_{ik}} - \frac{\dot{K}_{ik}}{\dot{Z}_{ik}},$$

which defines the rate of return to innovation.

I now consider entry/exit decisions. I assume that the cost of entry/exit is zero, existing firms do not have scrap value, and the value of not being active is zero. Hence, the number of firms is a jumping variable and an equilibrium with free entry/exit exists if $V_{ik} = 0$. Stock prices must satisfy the arbitrage condition

$$r = \frac{\Pi_{ik}}{V_{ik}} + \frac{\dot{V}_{ik}}{V_{ik}}.$$
Multiplying by $V_{ik} = 0$, observing that the left-hand-side is zero for any value of the interest rate, and realizing that $\tilde{V}_{ik} = 0$, the arbitrage condition yields the traditional zero-profit condition, $\Pi_{ik} = 0$, which reads

$$
\frac{1}{\xi_{ik}} \left[ LE_k \frac{P_{ik}^{1-\epsilon}}{P_k^{1-\epsilon}} + \sum_{s \neq k} LE_s \frac{(1+\tau)^{1-\epsilon} P_{ik}^{1-\epsilon}}{P_s^{1-\epsilon}} \frac{1}{1+\tau} \right] = \phi + LZ_{ik}.
$$

This equation states that firms break even in the sense that their cash flow just covers fixed management and R&D costs.

Assuming $\theta(\epsilon-1) < 1$, symmetry of this Nash equilibrium can be proved as in Peretto (1998, Proposition 1). Let variables without firm subscripts denote industry averages. I obtain:

$$
\begin{align*}
\tau &= \frac{LE \alpha (\xi - 1)}{\xi} \left[ S^D + \frac{c-1}{1+\tau} S^F \right] - \frac{K}{K}; \\
\frac{LE}{\xi} \left[ S^D + \frac{c-1}{1+\tau} S^F \right] &= \phi + LZ. 
\end{align*}
$$

(15)

(16)

where $\xi$ is the price elasticity of demand, $\alpha$ is the productivity of R&D, and $LZ$ is R&D expenditure per firm.

Notice now that the zero-profit condition can also be written $P_{ik} X_{ik} = L_{X_{ik}} + L_{Z_{ik}}$. Using this expression, in each country the labor market clearing condition $L = \sum_{i=1}^{N_k} (L_{X_{ik}} + L_{Z_{ik}})$ can be written $L = \sum_{i=1}^{N_k} P_{ik} X_{ik} \Rightarrow$

$$
L = \sum_{i=1}^{N_k} LE \left[ S^D_i + \frac{c-1}{1+\tau} S^F_i \right] \Rightarrow 1 = NE \left[ S^D + \frac{c-1}{1+\tau} S^F \right].
$$

Using the expressions for the market shares, I can then solve for

$$
E = \frac{1 + (1+\tau)^{1-\epsilon} (c-1)}{1 + (1+\tau)^{-\epsilon} (c-1)}.
$$

(17)

Expenditure is hump-shaped in $\tau$ because it depends on tariff revenues. The income effect of a higher tariff is positive as long as tariff revenues are increasing in $\tau$. The solution for the optimal intertemporal expenditure plan yields the saving schedule (3), which yields $\tau = \rho$ since (17) says that $E$ is a constant.$^7$

$^7$To make sure that the model is well specified, I need to check a couple of things. First, the balanced trade condition must hold. For country $k$, I have:

$$
\text{Imports} = \sum_{s \neq k} \sum_{i=1}^{N_s} LE_k \frac{(1+\tau)^{-\epsilon} P_{ik}^{1-\epsilon}}{P_k^{1-\epsilon}} = N (e-1) LE (1+\tau)^{-\epsilon} S^D;
$$

14
Using the expressions for the market shares and expenditure, treating the number of firms as a continuous variable, taking logs and time-derivatives of $K$, and observing that $\dot{Z} = \alpha L\dot{Z}$, I now use (15) and (16) to obtain

$$\dot{N} = \frac{[1 + (\gamma + \delta)(cN - 1)] [1 + \delta (cN - 1)]}{\gamma} \left[ \phi \alpha - \frac{L\alpha [1 - \theta (\xi - 1)]}{\xi N} \right].$$

This differential equation has a unique saddle-point steady state, which means that the economy is at all times on its balanced growth path with a constant number of firms determined by $(NN_{trade})$. Given that $\xi$ is decreasing in $\tau$, an increase in the tariff raises the right-hand side of the equation and causes $N$ to rise. Since $M = cN$, the global number of firms rises as well. ■

Exports

$$\text{Exports} = \sum_{i=1}^{N_k} \sum_{s \neq k} LE_s \frac{(1 + \tau)^{-\epsilon} \Pi_{ik}^{1-\epsilon}}{\Pi_{ik}^{1-\epsilon}} = N (c - 1) LE (1 + \tau)^{-\epsilon} S^D.$$ 

Since these expressions are equal, the condition is satisfied. Second, it must be that the combination of zero profit, labor market clearing and balanced trade yield the output market clearing condition that aggregate income be equal to aggregate expenditure, $L + T = LE$, where $T$ is tariff revenues. To prove that this is the case, notice that

$$\Pi_{ik} = P_{ik} X_{ik} - L_{X_{ik}} - L_{Z_{ik}}$$

$$\sum_{i=1}^{N_k} (L_{X_{ik}} + L_{Z_{ik}}) + \sum_{i=1}^{N_k} \Pi_{ik} = \sum_{i=1}^{N_k} P_{ik} X_{ik}$$

$$L + \sum_{i=1}^{N_k} \Pi_{ik} = \sum_{i=1}^{N_k} P_{ik} X_{ik}$$

$$L + \sum_{i=1}^{N_k} \Pi_{ik} = \sum_{i=1}^{N_k} P_{ik} X_{ik} + \sum_{s \neq k} \sum_{i=1}^{N_k} P_{ik} X_{is}^D$$

$$L + \sum_{i=1}^{N_k} \Pi_{ik} + T = \sum_{i=1}^{N_k} P_{ik} X_{ik} + \sum_{s \neq k} \sum_{i=1}^{N_k} (1 + \tau) P_{is} X_{is}^F$$

$$L + \sum_{i=1}^{N_k} \Pi_{ik} + T = LE_k.$$ 

On the left there is aggregate income, on the right aggregate spending. Since profits are zero, the symmetric model has $L + T = LE$. 

15
The following terms play a central role in the analysis. The term $\frac{L}{\xi N}$ is the *gross-profit effect*. It has two components: the first is a scale effect captured by total sales per firm, $\frac{L}{\xi}$; the second is a mark-up effect captured by the profit margin, $\frac{1}{\xi}$. The term $\theta (\xi - 1)$ is the *business-stealing effect* and captures the fact that by undertaking cost-reducing R&D the firm is able to offer lower prices and expand its market share. The gross-profit and business-stealing effects capture the market interaction of firms. The term $\alpha$ captures the *spillover effect* that stems from the technological interaction of firms: given R&D spending per firm, growth is higher when spillovers are stronger.

### 3.3 Growth

It is useful to define economic growth formally. In symmetric equilibrium all firms advance at the same pace. Moreover, in each country per capita consumption expenditure, $E$, and the number of domestic firms, $N$, are constant. Under these conditions, the rate of cost reduction,

$$g \equiv \frac{\theta}{\xi} \frac{Z}{Z} = \theta \alpha L Z,$$

determines the rate of growth of output, which is equal to the rate of growth of consumption.

Notice now that (15) yields the following R&D strategy of the firm

$$L Z = L \theta (\xi - 1) \frac{\rho}{\alpha}.$$

Solving (16) for $\frac{L}{\xi N}$, substituting the resulting expression into this equation, and using the definition of $g$, I obtain

$$g = \theta \phi \theta (\xi - 1) \frac{\alpha - \rho}{1 - \theta (\xi - 1)}; \quad (GG_{trade})$$

To interpret this equation, consider the two steps that I took to construct it. First, each firm takes the number of firms as given and solves an intertemporal optimization problem that yields the optimal price and R&D strategy. The symmetry of the model and the general equilibrium conditions imply that this strategy can be written as a function that maps the number of firms into the firm’s optimal level of R&D spending which, in turn, yields the rate of growth. Given the number of firms, this equation describes the Nash equilibrium of the oligopoly game that is the first building block of the model. Of course, the number of firms is endogenous and
must be determined by the zero-profit condition. In its usual interpretation, this equation determines the number of firms given that they undertake the optimal level of R&D spending. The second step in the construction of the GG locus is thus to substitute the zero-profit condition into the equilibrium R&D strategy obtained in the first step. The result is a modified version of the equilibrium R&D strategy that takes into account the fact that firms have perfect foresight about the effects of a parameter change on the zero-profit condition and correctly anticipate entry/exit. Figure 1 illustrates the resulting equilibrium.

There exists a critical value of the number of firms, \( N_0 \), such that growth is positive only if there are more than \( N_0 \) domestic firms in the market, which means that there are overall \( cN_0 \) firms in the global economy. Whenever growth is positive, moreover, it is increasing in the number of domestic firms although it is bounded from above. This turns out to be an important property. As population size, \( L \), increases, the number of domestic firms, \( N \), increases. Hence, the rate of growth of the global economy is an increasing function of population size that is bounded from above. In other words, the scale effect is positive but eventually vanishes (see Peretto and Smulders 1999 for a general discussion of this property in this class of models). The economic mechanism is the following. The larger population of the typical country generates a larger global market that raises firms’ gross profits (this is the gross-profit effect). This attracts entry, raises competition and induces firms to spend more on R&D (this is the business-stealing effect). However, as the number of firms becomes large, the positive effect of the larger market on the incentives to undertake R&D is fully offset by the fact that entry reduces the gross profit that firms earn on their innovations. Thus, when population is very large, a further increase in population size has no effect on the growth rate while it has a large effect on the number of firms.\(^8\)

### 3.4 Welfare

In symmetric equilibrium, the consumption index (7), the demand curve (9) and the price policy (14) yield

\[
\log C = \log (cN) + \log \left( \frac{\xi - 1}{\xi} \frac{1}{cN} \right) + \log Z^8.
\]

\(^8\)A discussion of the effects of the other parameters is available on request.
Substituting into (1) and integrating yields

\[ U = \frac{1}{\rho} \left[ \log (cN)^{\frac{\xi-1}{\xi}} + \log \left( \frac{1 - 1}{\xi} \right) \right]. \]

The terms \( \log (cN)^{\frac{\xi-1}{\xi}} \) and \( \log \left( \frac{1 - 1}{\xi} \right) \) capture the fact that utility is increasing in the number of consumption goods and the quantity of each consumption good; the term \( \frac{\xi}{\rho} \) captures the fact that utility is increasing in the rate of growth of consumption. Using \((GG_{\text{trade}})\), I can write

\[ U = \frac{1}{\rho} \left[ \frac{1}{\epsilon - 1} \log (cN) + \log \left( \frac{1 - 1}{\xi} \right) + \frac{\theta \phi \theta (\xi - 1) \alpha - \rho}{\rho (1 - \theta (\xi - 1))} \right]. \]

This is the equivalent of the \( GG \) locus in \((N,U)\) space. When the global industry equilibrium supports zero growth, utility is increasing in the number of firms because this yields a larger variety of consumption goods. Moreover, as the number of firms increases, the price elasticity of demand, \( \xi \), increases, prices fall, and consumption increases. As the number of firms reaches the critical level \( N_0 \) and firms start spending on R&D, entry leads to faster growth thus realizing further utility gains. One can use this locus to determine welfare at the market equilibrium by taking the equilibrium number of firms that obtains from \((NN_{\text{trade}})\) and substituting it into \((UU_{\text{trade}})\).9

\section{4 Autarky versus free trade}

Two definitions of autarky are possible in the context of this paper. One is that autarky entails no trade and no flows of knowledge. The other is that autarky entails no trade while flows of knowledge are allowed. In the former case, one obtains autarky simply by setting \( c = 1 \) in \((NN_{\text{trade}})\), \((GG_{\text{trade}})\) and \((UU_{\text{trade}})\). In the latter, one sets \( c = 1 \) in \((NN_{\text{trade}})\), \((GG_{\text{trade}})\) and \((UU_{\text{trade}})\) but leaves (11) unchanged. The two approaches produce similar results. I discuss only the first one.10

9 In the typical country, I look at a population of identical individuals at one point in time. If integration yields higher utility, it yields a Pareto improvement because it makes everybody better-off. Further welfare gains might be achieved by implementing policies that move the economy to the Pareto optimal allocation. These, however, are beyond the scope of the paper.

10 One could argue that this characterization of autarky is very restrictive because it implies that knowledge spillovers are embedded in trade flows. To the extent that knowledge is disembodied and intangible, an autarchic country with zero trade flows could enjoy positive spillovers from the rest of the world. This specification, however, does not change the qualitative results of the paper in a substantial way. I am indebted to Peter Thompson for pointing out this aspect of the model.
The equations that characterize the general equilibrium of the autarchic economy where the industry is in symmetric Nash equilibrium with free entry/exit and all markets clear are as follows:

\[ \phi = \frac{L}{\xi N} \left[ 1 - \theta (\xi - 1) \right] + \frac{\rho}{\alpha}; \quad (NN_{\text{autarky}}) \]

\[ g = \theta \frac{\phi \theta (\xi - 1) \alpha - \rho}{1 - \theta (\xi - 1)}; \quad (GG_{\text{autarky}}) \]

\[ U = \frac{1}{\rho} \left[ \frac{1}{\epsilon - 1} \log N + \log \frac{\xi - 1}{\xi} + \frac{\theta \phi \theta (\xi - 1) \alpha - \rho}{\rho \left( 1 - \theta (\xi - 1) \right)} \right], \quad (UU_{\text{autarky}}) \]

where

\[ \xi \equiv \frac{\epsilon (N - 1) + 1}{N} \quad (18) \]

is the price elasticity of demand and

\[ \alpha \equiv \frac{1 + (\gamma + \delta) (N - 1)}{1 + \delta (N - 1)} \quad (19) \]

is the productivity of R&D.

Comparing \((GG_{\text{trade}})\) and \((UU_{\text{trade}})\) to \((GG_{\text{autarky}})\) and \((UU_{\text{autarky}})\), one notices the following differences. First, the price elasticity of demand is given by \((10)\), which is larger than \((18)\) for all \(N\). Second, spillovers are given by \((11)\), which is larger than \((19)\) for all \(N\). Third, in \((UU_{\text{trade}})\) there is the extra term \(\frac{1}{c-1} \log c\), which captures the fact that trade allows access to a larger variety of goods.\(^{11}\) As a result, \((GG_{\text{trade}})\) and \((UU_{\text{trade}})\) are everywhere above \((UU_{\text{autarky}})\) and \((GG_{\text{autarky}})\).

Figure 1 illustrates the market equilibrium of the global economy in comparison to the market equilibrium of the autarchic economy. Let \(N^*\) be the equilibrium number of domestic firms in autarky. A move from autarky to trade – free or restricted by tariffs – corresponds to an exogenous increase in the price elasticity of demand, \(\xi\), and R&D productivity, \(\alpha\), for all levels of the number of domestic firms, \(N\). That is, the terms \(\xi(N)\) and \(\alpha(N)\) are replaced by \(\xi(cN)\) and \(\alpha(cN)\). Alternatively, it takes the form of a change

\(^{11}\)This property of the welfare function is independent of the specification of spillovers. If I use the same expression for spillovers in \((UU_{\text{autarky}})\) and \((UU_{\text{trade}})\), the term \(\frac{1}{c-1} \log c\) due to the wedge between domestic goods and world goods does not disappear.
Figure 1: Market equilibrium with trade and in autarky
in the number of firms from $N$ to $M = cN$ that preserves the shape of the functions $\xi(\cdot)$ and $\alpha(\cdot)$. As it is apparent from the figure, the effects of such a move are potentially ambiguous because the number of domestic firms falls. I can, however, resolve the ambiguity and obtain sharp predictions. To do so, I first compare autarky to free trade and then look at the incremental effects of the tariff rate.

Let $N^{**}$ be the equilibrium number of domestic firms in free trade. Figure 2 and the following two propositions characterize the differences between autarky and free trade.

**Proposition 3** The global number of firms in free trade is larger than the number of domestic firms in autarky, which is larger than the number of domestic firms in free trade, $M^{**} = cN^{**} > N^{*} > N^{**}$.

**Proof.** By definition, $N^{*}$ and $N^{**}$ are such that:

$$\phi = \frac{L}{N^{*}} \left(1 - \frac{\theta}{\xi(N^{*})} \right) + \frac{\rho}{\alpha(N^{*})}; \quad (20)$$

$$\phi = \frac{L}{N^{**}} \left(1 - \frac{\theta}{\xi(cN^{**})} \right) + \frac{\rho}{\alpha(cN^{**})}. \quad (21)$$

The right-hand side of these equations is decreasing in $N$, $\xi(\cdot)$ and $\alpha(\cdot)$. Comparing the two equations, one sees that for a given $N$ integration raises $\xi(\cdot)$ and $\alpha(\cdot)$. Hence, $N^{**} < N^{*}$. Now replace $cN^{**}$ with $M^{**}$ in the second equation to obtain

$$\phi = \frac{cL}{M^{**}} \left(1 - \frac{\theta}{\xi(M^{**})} \right) + \frac{\rho}{\alpha(M^{**})}. \quad (22)$$

The right-hand side of this expression is decreasing in $M$. Comparing (20) and (22), one sees that the effect of free trade is to multiply $L$ by $c$ while the shape of $\xi(\cdot)$ and $\alpha(\cdot)$ is preserved. It follows that $M^{**} > N^{*}$. ■

Inspection of (21) shows the forces behind the fall in the number of domestic firms. First, there is a negative gross-profit effect because the higher price elasticity of demand reduces mark-ups and market shares. Second, there is a positive business-stealing effect that induces higher R&D spending and reduces the number of firms that the market supports in zero-profit equilibrium. Third, the stronger spillovers raise R&D productivity and induce higher R&D spending, which further reduces the number of firms.
Figure 2: The number of firms in autarky and free trade
Thus, domestic firms are squeezed out by a combination of falling cash flow and escalating R&D spending. This illustrates the crucial property of the model: a move from autarky to free trade leads to exit of domestic producers while domestic consumers gain access to foreign goods and the surviving domestic producers gain access to foreign knowledge. This change in market structure is beneficial.

**Proposition 4** Growth and welfare in autarky are lower than in free trade.

**Proof.** Consider \((GG_{\text{trade}})\) and \((UU_{\text{trade}})\), set \(\tau = 0\), and replace \(cN\) with \(M\). This yields:

\[
g = \phi \theta (\xi - 1) \alpha - \rho; \]

\[
U = \frac{1}{\rho} \left[ \frac{1}{\epsilon - 1} \log M + \log \frac{\xi - 1}{\xi} + \frac{\theta \phi \theta (\xi - 1) \alpha - \rho}{\rho \left( 1 - \theta (\xi - 1) \right)} \right],
\]

with

\[
\xi = \epsilon - (\epsilon - 1) \frac{1}{M}
\]

and

\[
\alpha = \frac{1 + (\gamma + \delta) (M - 1)}{1 + \delta (M - 1)}.
\]

Now notice that these equations have the same shape as \((NN_{\text{autarky}})\) and \((UU_{\text{autarky}})\). Hence, to compare growth and welfare in autarky and free trade one simply needs to evaluate them at, respectively, \(N^*\) and \(M^{**}\). Since both equations are increasing in their arguments, \(g^{**} > g^*\) and \(U^{**} > U^*\). ■

The proof of this proposition – perhaps not surprisingly – emphasizes that the growth and welfare gains due to a move from autarky to free trade stem from the increase in the number of firms that operate in each market.\(^{12}\) It is the increase in competition, together with the increase in the variety of goods and sources of knowledge spillovers, that drives the faster growth and higher lifetime utility attained in free trade.

\(^{12}\) A move from autarky to free trade entails *global exit* in the sense that the global number of firms falls. In a world where all countries are autarchic there are \(cN^*\) firms, while in a world with free trade there are \(cN^{**}\) firms. Since \(N^* > N^{**}\), the global number of firms in a world of free trade is lower than in an autarchic world.
An important aspect of this result is that the scale effect behind it – the relation between the growth rate and the size of the market – is non-linear. For economies that do not support growth in autarky, integration produces the conditions for positive growth if the number of integrating countries is sufficiently large. Consider, for example, an economy with fundamentals such that \( N^* < N_0 \), which yields \( g(N^*) = 0 \). It is always possible to find a number of trading partners sufficiently large so that \( g(cN^{**}) > 0 \). This threshold-crossing effect is due to the property that the scale effect is stronger the smaller the economy. Notice, moreover, that this scale effect does not run from the country’s population to its growth rate because the country does not have access to foreign labor and thus its resources endowment is unchanged. This means that the positive growth effect of integration is due to the firm’s access to a larger, more competitive market where larger means that the number of customers is larger (a demand side effect), not the number of workers (a supply side effect). Finally, the growth effect of integration is bounded from above. It is large for small economies with much market power and is negligible for large economies that approach monopolistic competition where the price elasticity of demand approaches the upper bound \( \varepsilon \) and spillovers approach the upper bound \( \frac{2+6}{7} \).

5 The effects of a global reduction in tariffs

At this point, one should notice the importance of my characterization of the international economy as a global, differentiated oligopoly. In the literature on market structure and trade it is customary to posit monopolistic competition – as opposed to deriving it as the limit of the oligopoly model when the number of firms becomes very large – by assuming that there is a continuum of goods. With such an assumption, the price elasticity of demand faced by firms is always \( \varepsilon \) regardless of the tariff. Inspection of \( (NN_{trade}) \) then reveals that a global reduction in tariffs has no effects. One way to recover effects of the tariff is to reformulate the model by allowing for non-tradeable goods. A global reduction in tariffs then leads to an expansion of the tradeable sector with respect to the untreadable one. Such effects, however, do not stem from changes in market structure within industries. This points out that the model that I set up in this paper successfully isolates the effects of tariffs on competition in international oligopolies.\(^{13}\)

---

\(^{13}\)Alternatively, one could follow Venables (1987) and study the effects of unilateral trade policy. This, however, would not help us understanding the effects of globalization as driven by the worldwide reduction in trade frictions due to the GATT in the past and
Figure 3 illustrates the effects of a global reduction in tariffs. The $GG$ locus shifts up because the higher price elasticity of demand raises the incentives to engage in cost reducing R&D. The number of domestic firms, on the other hand, is smaller and this entails a movement down along the $GG$ locus. As a result, the growth effect is ambiguous. The intuition is as follows. When $\tau$ decreases, firms experience tougher price competition; this raises the business stealing effect and induces them to rise R&D spending. The direct effect of lower tariffs is thus to boost growth. However, the fall in the number of domestic firms, which corresponds to a fall in the global number of firms, reduces global competition in the sense that in each market in which the firm sells it faces fewer rivals. This reduces the business-stealing effect and induces firms to reduce R&D. In addition, spillovers are weaker. Hence, the indirect effect of lower tariffs tends to reduce growth. A similar story applies to welfare. The $UU$ locus shifts up because lower tariffs raise price competition. Holding constant the number of domestic firms, this lowers the mark-ups that firms charge and this allows consumers to buy larger quantities of goods. Moreover, the stronger business-stealing effect induces firms to speed up growth. However, because some firms go out of business, the variety of consumption goods and of sources of spillovers falls and this has a negative effect on welfare and a negative effect on growth, which has a further negative effect on welfare. These forces show up as a movement down along the new, higher $UU$ locus.

Overall, there is a tension between the benefits of product and knowledge variety that tariffs protect and the costs of smaller firm size that leads to less exploitation of economies of scale. In other words, there is a tension between external and internal increasing returns. Tariffs raise the number of firms and thus foster external economies – love of variety for consumers and technological spillovers for producers. On the other hand, the larger number of firms prevents the individual firm from fully realizing internal economies of scale due to fixed management costs and dynamic increasing returns in R&D. I refer to the effects of a reduction in tariffs as the homogenization and rationalization effects. It is important to notice that the homogenization effect described here is opposite to the diversity effect (Helpman and Krugman 1985, p. 264) that drives the welfare gains that countries realize when moving from autarky to free trade. This discussion “proves” the following proposition.

**Proposition 5** The growth and welfare effects of a global reduction in tariffs are negative (positive) if increasing returns external to the firm due to love

the WTO today.
Figure 3: The effects of a global reduction in tariffs
of variety and spillovers dominate (are dominated by) increasing returns internal to the firm due to fixed management and R&;D costs.

So far I have focused on the local effects of the tariff. I now look at its global effects. To this end, the following limiting results help.

**Proposition 6** For $\tau \to \infty$ ($NN_{\text{trade}}$) yields $N = N_\infty$ with $N^{**} < N_\infty < N^* < cN^{**} < cN_\infty$. Moreover, $g^* < g_\infty < g^{**}$ and $U^* < U_\infty$.

**Proof.** For $\tau \to \infty$ ($NN_{\text{trade}}$) reduces to

$$\phi = \frac{L}{N_\infty} \left( 1 - \theta \frac{\xi(N_\infty) - 1}{\xi(N_\infty)} \right) + \frac{\rho}{\alpha(cN_\infty)}, \quad \xi(N_\infty) = \epsilon - (\epsilon - 1) \frac{1}{N_\infty}. \quad (23)$$

The right-hand side of (23) is smaller than that of ($NN_{\text{autarky}}$) for all $N$ since $\alpha(cN) > \alpha(N)$. Hence, $N_\infty < N^*$. Now replace $N$ with $M$ to obtain

$$\phi = \frac{cL}{M_\infty} \left( 1 - \theta \frac{\xi(M_\infty) - 1}{\xi(M_\infty)} \right) + \frac{\rho}{\alpha(M_\infty)}, \quad \xi(M_\infty) = \epsilon - (\epsilon - 1) \frac{c}{M_\infty}. \quad (24)$$

Comparing ($NN_{\text{autarky}}$) and (24), one sees that the two equations differ by the term $c$ that multiplies $L$ in (24) and by the fact that the expression for the price elasticity of demand is lower in (24). As a result, the right-hand side of (24) is larger than the right-hand side of ($NN_{\text{autarky}}$) for all $N$ and $M$. Since the two expressions are decresing in, respectively, $N$ and $M$, one obtains $N^* < M_\infty = cN_\infty$. The inequality $N^{**} < N_\infty$ follows from the fact that for all $N$ the price elasticity of demand is larger in (21) than in (23). One can now follow the logic of proposition 4 to show that $g^* < g_\infty$ and $U^* < U_\infty$. Finally, notice that $g^{**} > g_\infty \iff \xi(N^{**}) - \xi(N_\infty) \mid (\phi\alpha - \rho) > 0$. The last inequality is true because $\phi\alpha > \rho$ and $\xi(N^{**}) > \xi(N_\infty)$. ■

If one recalls that the number of domestic firms is monotonically increasing in the tariff, these limiting results allow one to conclude that for all values of the tariff the number of domestic firms and the global number of firms are, respectively, smaller and larger than the number of domestic firms in autarky. In other words, \textit{autarky yields the largest number of domestic producers and the smallest number of available goods, that is, the smallest number of firms operating in the domestic market}. This provides the intuition behind the next result: \textit{trade dominates autarky for all values of the tariff in the sense that growth and welfare are always higher}. The reason is that, regardless of the value of the tariff, trade allows a country to consume
a larger variety of goods than it produces while the larger number of firms generates tougher competition and stronger spillovers that support faster growth. Finally, the limiting result that $g^{**} > g_{\infty}$ allows one to conclude that the relation between growth and the tariff is at most hump-shaped – growth could be increasing for small values of the tariff but eventually must be decreasing in the tariff. In fact, inspection of $(GG_{\text{trade}})$ suggests that growth is monotonically decreasing in the tariff if the direct effect of the tariff on the price elasticity of demand dominates the indirect effect,

$$\frac{d\xi}{d\tau} = \frac{\partial \xi}{\partial \tau} + \frac{\partial \xi}{\partial N} \frac{\partial N}{\partial \tau} < 0.$$  

This sufficient condition is likely to hold in reality. Unfortunately, I do not have a similar result for welfare because of the extra term $\frac{1}{cN} \log (cN)$ in $(UU_{\text{trade}})$, which also does not allow me to prove that $U^{**} > U_{\infty}$. In other words, the relation between welfare and the tariff could be monotonically increasing. This, however, would require implausibly strong external increasing returns. Overall, the model suggests that the relations between growth and welfare and the tariff are either monotonically decreasing or hump-shaped. Figure 4 illustrates my conclusions.\footnote{These results establish an important difference between my work and the contributions of Rivera-Batiz and Romer (1991b) and Baldwin and Forslid (1999, 2000) who obtain U-shaped relationships between the ad-valorem tariff and growth. First, in their models the tariff affects only a firm’s level of sales in foreign markets and not the markup of price over marginal cost. Second, the number of firms is fixed so that there is no additional feedback due to the endogenous structure of the market. The second channel is most important. If I assume that the number of firms is fixed, I obtain that growth increases linearly with population size and decreases monotonically with the tariff. The latter result stems purely from the direct effect of the tariff on the price elasticity of demand since this version of the model shuts down the possibly offsetting indirect effect.}

## 6 Understanding the differences

Figure 5 provides a graphical comparison of the two exercises undertaken in the previous sections. Starting from free trade, $\tau = 0$, and increasing $\tau$, the $GG$ locus in $(N, g)$ space shifts down, reflecting the fact that protection reduces competition and thus induces firms to cut R&D spending. The number of firms, on the other hand, rises, reflecting the fact that protection makes domestic firms more profitable and thus attracts entry. For $\tau = \infty$, the equilibrium is at the intersection of the dashed lines, $(N_{\infty}, g_{\infty})$, which is not autarky. Only if one posits that spillovers in autarky are $\alpha (cN)$ – reflecting the fact that flows of intangible knowledge are not embedded in
Figure 4: The relation between the tariff and growth and welfare
Figure 5: The relation between autarky and the limit of the trade model
trade flows so that domestic firms benefit from foreign knowledge even if there is no trade – the equilibrium for an infinite tariff is at the autarky point \((N^*, g^*)\).

In \((N, U)\) space, there is a wedge between the \((UU_{\text{autarky}})\) and \((UU_{\text{trade}})\) loci due to the fact that consumers have access to the entire menu of goods produced in the world for all possible levels of the tariff. Hence, even if one posits that spillovers in autarky are \(\alpha(cN)\), the relation \(M = cN\) prevents the \(UU\) locus to converge to the one that applies in autarky. There is thus a crucial difference between the exercise that compares autarky to free trade and the exercise that looks at an incremental reduction in tariffs.\(^{15}\)

Where does this difference come from? In the case of a global reduction in tariffs, there cannot be entry of foreign firms in the domestic market because all firms operate in all markets to begin with. Hence, the only effect that the model can capture is the loss of market power of domestic firms due to lower tariffs with the consequent fall in net profits that squeezes out some firms. As a consequence, looking at an incremental trade liberalization gives a different answer from comparing autarky to trade.

Consider first the experiment discussed in Section 4. When the economy is opened to trade, each firm faces a market where the number of customers and the number of competing firms have increased in the same proportion, so that sales per firm do not change, but where tougher competition reduces firms' market power and yields lower mark-ups and profit margins. As a result, in each country the domestic number of firms falls. From the viewpoint of the consumer, however, exit of domestic producers is more then compensated by entry of foreign firms that are now free to export to the consumer’s country. More generally, integration produces a major change in industrial market structure: the integrated market is larger and concentration is lower. The important result is that firms in a larger, more competitive market spend more on R&D – which is also more productive because spillovers are stronger – so that growth is faster. Welfare increases because the global number of firms in the integrated market is larger than the number of domestic firms in autarky, while tougher competition forces firms to charge lower mark-ups and prices.\(^{16}\) Interestingly, and intuitively,

\(^{15}\)I emphasize that this property does not depend on my definition of autarky as a situation where knowledge spillovers across countries are zero. Rather, it follows from the property of the CES preferences that the marginal utility of each good is infinity for a quantity that approaches zero. This means that domestic consumers buy all foreign goods even if the tariff is very large so that the effect of the tariff is absorbed by the quantity of each good, not by the number of goods.

\(^{16}\)Recall that prices fall over time because of falling costs: the statement compares prices
this mechanism is at work also in the case of a move from autarky to trade restricted by tariffs. Hence, one can conclude:

**Summary 7** A move from autarky to trade – free or restricted by ad-valorem tariffs – raises growth and welfare because it generates a larger, more competitive market where producers have access to a larger number of customers and a larger body of knowledge spillovers, while consumers have access to a larger variety of cheaper goods. Hence, the quantity, variety and growth of consumption rise.

Consider now the experiment discussed in Section 5. The competitive effect of integration reduces firms’ market power and yields lower mark-ups and profit margins. The crucial result is that the global number of firms falls. The consumer now sees exit of domestic and foreign firms. Integration, therefore, leads to a market that is of the same size – because the number of customers has not changed – while concentration is higher. There is thus a tension between the effect of the lost protection in the domestic market and the effect of the larger share of the global market that each firm now commands. On the other hand, spillovers are now weaker because some sources of knowledge are lost due to exit. In principle, the growth effect is ambiguous. Similarly, the welfare effect is ambiguous because the variety of consumption goods is smaller while, partially compensating this, firms have less market power and charge lower mark-ups. I have been able to show that the relation between growth and the tariff is either decreasing or hump-shaped. Under reasonable conditions, the relation between welfare and the tariff exhibits a similar property. One can thus conclude:

**Summary 8** A global reduction in tariffs triggers a trade-off between internal and external economies of scale. The variety of sources of knowledge spillovers and of consumption goods falls. This homogenization effect tends to reduce growth and welfare. On the other hand, firms become larger while tougher competition induces them to reduce mark-ups, which allows consumers to buy larger quantities of the available goods, and raise R&D spending. This rationalization effect tends to raise growth and welfare. The balance of these forces is such that growth and welfare generally increase with the reduction in tariffs except at sufficiently low values of the tariff where it is possible that they decrease.

These experiments suggest that to determine whether “integration lets countries exploit increasing returns in R&D” one needs first to specify the

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at two different equilibria, not at different moments in time.
form of integration and, more importantly, to be very clear about the setup. The first experiment produces results that match conventional intuition on the benefits of international trade: larger markets, more competition, more choice. This is because by construction one is looking at a shock that entails an increase in the number of firms that serve domestic consumers. The second experiment shuts down this channel. In so doing, it focuses attention on the opposite extreme where the shock entails a reduction of the number of firms that serve domestic consumers. In other words, the results for the case of incremental liberalization depend crucially on the property that the wedge between the number of domestic producers and the number of goods available to consumers does not depend on the tariff because the relation \( M = cN \) holds. This means that \( N \) and \( M \) are constrained to move in the same direction and thus from the viewpoint of the domestic consumer exit of domestic firms is bound to yield exit of domestic and foreign firms. As a result, the growth and welfare effects of integration depend on the relative importance of increasing returns internal to the firm and increasing returns external to the firm. A global reduction in tariffs is beneficial when the love of variety effect is weak and technological spillovers do not change much with the number of firms. To some extent, these results also match conventional intuition expressed in complaints like “globalization is making the world more homogeneous” that it is common to hear today.

7 Conclusion

I discussed the role of economic integration in a model of endogenous growth where the size of the firm and the interactions between growth and the endogenous structure of the market play a crucial role. In contrast to previous work based on first-generation models of endogenous innovation (e.g., Grossman and Helpman 1991, Rivera-Batiz and Romer 1991a, 1991b, and Baldwin and Forslid 1999, 2000), I focused on a model of Schumpeterian innovation undertaken in-house and characterized by partial knowledge spillovers. This allowed me to analyze the effects of integration on competition, R&D activity, and ultimately on growth and welfare in a world economy populated by global oligopolists.

I provided a characterization of the conditions under which integration improves growth and welfare. To summarize, a move from autarky to trade – even if trade is restricted by tariffs – raises growth and welfare because it generates a larger, more competitive market where firms have access to a larger body of technological spillovers. A global reduction in tariffs has
potentially ambiguous growth and welfare effects because there is a trade-off between internal and external economies of scale. Growth and welfare rise if the rationalization effect dominates the homogenization effect.

I have discussed the reason why looking at an incremental trade liberalization gives a different answer from comparing autarky to trade. An interesting direction for future research is to develop a model that reconciles these different perspectives. Such a model should have the property that the wedge between the number of goods produced domestically and the number of goods consumed be a function of trade policy. To my knowledge there is no model with this property in the literature.

References


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