DISCUSSION PAPERS IN ECONOMICS

Competition and Growth in the Global Economy: Exports vs. FDI

Javier Andres Santiago
University of Colorado Boulder

October 24, 2018

Competition and Growth in the Global Economy: Exports vs. FDI

Javier Andres Santiago

University of Colorado at Boulder[†]

JOB-MARKET PAPER

This version: October 24, 2018

Latest version here

Abstract

This paper develops a two-country model of endogenous growth with step-by-step innovation and oligopolistic competition where firms serve their foreign market via exports or horizontal FDI. The process of international competition equalizes long-run growth across countries, which depends on the innovation rates of individual firms and the distribution of industries over international technological differences. A quantitative analysis of the model based on some long-run salient features of high-income countries shows that the effects of changes in trade barriers on economic growth vary with the size of barriers to FDI. Bilateral trade liberalization from high to moderate barriers yields an increase in growth from 1.79% to 2.33% when FDI barriers are high, but leaves growth unaffected when FDI barriers are low. Subsequent liberalization towards free trade decreases growth for both high and low FDI barriers because of an excessive-competition effect. Unilateral movements to higher or lower trade protection when trade and FDI costs are low decrease growth in both countries through an additional relative-market-size effect. The results highlight the importance of considering the size of barriers to both trade and FDI when analyzing the effects of trade or investment liberalization on economic growth.

Keywords : Economic growth, competition, innovation, international trade, foreign direct investment

JEL codes : F43, O31, L11, L22

I am very grateful to Wolfgang Keller, Keith Maskus, James Markusen, Jeronimo Carballo, Sergey Nigai, Carol Shiue, Taylor Jaworski, and Alessandro Peri for invaluable guidance and support. I also thank participants at the University of Colorado International Trade and Macroeconomics workshops for many helpful comments. Finally, I am very grateful to the Department of Economics and the Graduate School at the University of Colorado for all the generous funding during the realization of this project. All remaining errors are my own.

[†] Department of Economics, 256 UCB, 80309-0256; javier.andressantiago@colorado.edu

1 Introduction

How does openness to trade and multinational production among high-income countries a ect competition and economic growth in those countries? This is a very important issue, particularly in the context of the current wave of protectionism, that can a ect the standard of living of future generations in developed countries. To address this question, in this paper I develop and quantitatively solve a model of endogenous growth to examine the long-run e ects of reducing or increasing barriers to trade and foreign direct investment (henceforth FDI) on economic growth, focusing on the e ects that are mediated by changes in the competitive environment.

Most of the trade and FDI ows in the world take place among high-income countries (Markusen 2002, United Nations 2017). Moreover, despite some evidence of complementarity between trade and FDI from intra- rm trade (Lipsey and Weiss 1984, Clausing 2000), horizontal a perfectly-competitive sector by means of a production function that combines domestic labor and a large number of domestic and foreign intermediate inputs. Both countries produce the same range of intermediate inputs, so the model abstracts from any gains from variety. Within each intermediate input industry there are two firms, one from each country, that differ in terms of productivity and that compete in prices à la Bertrand for both the domestic and the foreign markets. Serving the domestic market only involves production costs determined by technology. But firms face a trade-off when deciding how to serve the foreign market. They can do so via exports, bearing the variable costs associated with trade (transportation costs, tariffs, etc.), or they can do horizontal FDI, which avoids those variable costs but is subject to fixed costs related to producing and selling in the foreign country (such as the costs of maintaining production facilities or a distribution network abroad). It is the size of these barriers to trade and FDI that determines which alternative is chosen by firms to serve their foreign markets, and how competitive both the domestic and foreign markets are.

While firms can in general differ in terms of their production technologies, they can invest resources in research and development (henceforth R&D) to gradually improve that technology over time. This generates a steady-state equilibrium with a stationary distribution of intermediate good industries over international technological differences. Some industries will be characterized by firms that have the same productivity, while other industries will have one of the firms (from either country) ahead of the other in terms of productivity.

In the steady-state equilibrium, economic growth in each country is a function of the size of innovations, the innovation intensities of domestic firms, and the international distribution of industries over technology gaps. Interestingly, regardless of the size of barriers to trade and FDI, and in the absence of technological spillovers, the rates of economic growth are equalized across countries. This equalization result is explained by the process of international competition in each industry. For any given country, and any given industry, the good will be produced by either the domestic or the foreign firm. If produced by the foreign firm, the dependence of domestic growth on foreign technology is evident. But even if the good is produced by the domestic firm, foreign technology also plays a role by determining how much competitive pressure the foreign firm exerts on the domestic firm, and hence the price charged and quantity produced by the latter.

The fact that the rates of economic growth are equal across countries regardless of the size of barriers to trade and FDI does not mean that both countries will have the same relative economic size. The latter depends crucially on how high or low trade and FDI costs are, although this dependence is mediated by the endogenous distribution of industries across technological differences. While this cannot be solved for analytically, I perform numerical analyses that illustrate this property of the equilibrium.

I calibrate the model using reasonable parameter values from the endogenous growth literature to match some salient features of high-income countries such as a long-run growth rate of about 2% per year, and I perform experiments where I analyze the effect of different combinations of trade and FDI barriers on economic growth. The results of bilateral experiments, where the two countries are symmetric in terms of their barriers of barriers to FDI. For example, reducing trade barriers from very high to moderate levels increases long-run economic growth from 1.79% to 2.33% if barriers to FDI are high. However, if barriers to FDI are low in the first place, changes in trade barriers in the moderate-to-high range have no effect on economic growth. This is because trade and horizontal FDI are substitute ways for firms to sell to foreign customers. If FDI barriers are sufficiently low, then no matter how low trade barriers are, FDI will be a more profitable way of competing in foreign markets.

Further reductions in trade barriers from a moderate level to free trade actually decrease economic growth, regardless of whether FDI barriers are high or low. This is because reducing market-access barriers to a very low level gives rise to what I call an *excessive-competition effect*, whereby the increase in competition brought about by the lower barriers makes firms with similar technologies innovate so much, and firms in industries with high technology gaps so little, that the equilibrium distribution of industries over technology gaps features a large proportion of industries of the second type, which lowers aggregate innovation and economic growth. The excessive-competition effect is closely related to the inverted-U effect highlighted in closed-economy endogenous growth models (see, for example, Aghion et al. 2005). The difference is that in open economies with barriers to trade or FDI, innovation incentives are determined, not just by technological differences, but also by the size of

Impullitti and Licandro 2018). The results of this paper show the importance of considering both trade and FDI when analyzing the effects of globalization on economic growth. This is a first step in that direction.

The paper also contributes to the international trade and economic growth literature by focusing on the role of trade and FDI in shaping the competitive environment firms compete in. Most of the trade and growth literature (pioneered by Grossman and Helpman 1991) puts the emphasis on the role of higher openness in generating technological spillovers from either importing goods or allowing foreign firms to establish their production plants

good sector. Workers cannot work in the intermediate good sector or migrate to the other country.

Utility maximization yields the standard Euler equation:

$$g_i^C(t) \quad \frac{\dot{C}_i(t)}{C_i(t)} = r_i(t) \tag{3}$$

where $g_i^C(t)$ denotes the growth rate of consumption in country i at time t. This growth rate will be constant in the steady-state equilibrium derived below.

2.3 Final Goods

The final good in country i is produced by many firms in a perfectly-competitive environment by combining labor and a continuum of intermediate inputs according to a constant-returns-to-scale production function,

$$Y_i(t) = (A_i L_i)^{1} \quad \exp \int_0^1 \ln(X_i(j;t))\, dj \quad ; \qquad 0 < \quad < 1; \tag{4}$$

where $Y_i(t)$ denotes final output, A_i is an efficiency parameter (constant over time), and is the elasticity of final output with respect to intermediate inputs (or the share of expenditure on intermediate inputs). $X_i(j;t)$ denotes the quantity of intermediate good j used in the production of the final good in country i. Intermediate goods can be sourced from domestic firms, or from foreign firms by either importing the product or buying it locally from a foreign affiliate plant. The final good, in turn, can be used for consumption, research, and intermediate good production by either domestic firms or foreign firms that serve country-i

$$w_i(t) = (1 \qquad) \frac{Y_i(t)}{L_i} \tag{6}$$

$$p_i(j;t) = \frac{Y_i(t)}{X_i(j;t)} \qquad j \ 2 \ [0;1] \tag{7}$$

Rearranging (7) yields the demand for intermediate input j coming from country-i's nal good sector:

$$X_i(j;t) = \frac{Y_i(t)}{p_i(j;t)} \qquad j \ 2 \ [0;1] \tag{8}$$

Intermediate good producers for variety j take (8) as given (for both markets, $i = H$ and $i = F$) when solving their own pro t-maximization problems.

2.4 Intermediate Goods

2.4.1 Technology and Costs

Each intermediate good industry is characterized by an oligopolistic environment in which two in nitely-lived rms, one from each country, competeà la Bertrand for their domestic and foreign markets. Within an industry, each rm produces its own variety of intermediate product, but the two varieties are assumed to be perfect substitutes. Since there is only one rm per country producing intermediate good j, rms are indexed by their country of origin $i \ 2 \ f \ H;F \ g$.

Production by each rm is done by means of a linear technology that requires $MC_i(j;t) = 1 = q(j;t)$ units of the nal good to produce 1 unit of its intermediate good variety, where $q_i(j;t)$ denotes the productivity level of rm i producing intermediate good j. This productivity level is indexed by t because it can be improved upon if the rm invests resources in R&D and undertakes a successful innovation. Firms are heterogeneous in terms of their productivity (i.e., of their marginal production cost, $MC_i(j;t)$), de ned as

$$q_i(j;t) = \quad ^{n_i(j;t)}; \tag{9}$$

where $\ > \ 1$ and $n_i(j;t) \ 2 \ Z_+$ denotes the number of succesful innovations undertaken by rm i up to time t. In other words, $n_i(j;t)$ indexes (n03(tec)28(ind28(y)-329(le7nno)28(ind2(to)-351(time)]TJ/F11 116.97 Tf 49.797 0 Td [(t)]TJ of competition and growth in closed economies such as Aghion et al. (2001) or Acemoglu and Akcigit (2012), where the technology gap is defined as a nonnegative integer because the identities of the leader and the follower are irrelevant. In this open-economy setting, however, the existence of barriers to trade and FDI (see below) that differ across countries makes it convenient to define the technology gap as in (10).[4]

Markets are segmented. When a firm competes for its domestic market, it faces no other cost than the one from producing its own variety ($MC_i(j;t)$). When competing for its foreign market, however, each firm has two alternative options to serve that market. On the one hand, a firm can produce in its own country and export its product to the foreign market. In that case, the firm faces not only its production cost but also a variable trade cost. Trade costs are assumed to be of the "iceberg" form, with $\tau_d MC_i(j;t) \geq MC_i(j;t)$ denoting the total variable unit cost of serving country $d \in \{H;F\}$ $(i \neq d)$ via exports.[5] This trade cost can be interpreted in a broad way encompassing both transportation costs or import tariffs.[6]

On the other hand, a firm competing for its foreign market can avoid bearing the variable trade cost τ_d by engaging in horizontal FDI, that is, by setting up a production plant in the foreign country to serve the customers (the final good sector) of that country locally. However, this alternative is subject to a fixed cost $K_d(t) = \kappa_d Y_d(t)$ that depends on the size of the destination market, $Y_d(t)$, and an index of barriers to FDI in that market, $\kappa_d \in [0;1]$. The latter captures various barriers that make maintaining production facilities or an efficient distribution network abroad costly. One could think of different barriers such as language or cultural differences that make it difficult to maintain relationships with foreign workers, or overcome regulatory barriers in the destination market.[7] Although establishing and maintaining distribution channels abroad also matters for exporters, their fixed costs of doing so are normalized to zero. Thus, the fixed cost of FDI in the model captures the cost above and beyond the fixed cost faced by exporters. The index can also reflect difficulties in transferring technology from the firm's headquarters to the affiliate production plant. Here it is assumed those costs don't vary with the distance to the destination market, although as shown by Keller and Yeaple (2013), gravity is an important factor in determining technology transfer costs. As with the trade costs, FDI barriers in the model are broadly defined.

Notice that while the index of barriers to FDI is constant over time, the total fixed costs of FDI do vary over time because of the market size component. One can interpret this as reflecting the difficulties in maintaining capacity, a distribution network, or transferring technology to a larger market, which are all the more difficult in the presence of the barriers captured by κ_d. While dealing with a larger market is a problem that domestic firms would presumably also have to face, here I simplify the analysis by assuming the latter don't have to incur

[4] The fact that the technology gap is defined as the difference between $n_H(j;t)$ and $n_F(j;t)$ and not the other way around is without loss of generality.

[5] That is, for 1 unit of the good to arrive at the destination market, $\tau_d \geq 1$ units have to be produced. The extra units $\tau_d - 1 \geq 0$ "melt" in transit.

[6] For welfare analysis the distinction between the two is important. While tariff revenue can be rebated to households, transportation costs cannot. Here the distinction is not relevant because the focus of the paper is on the effect of barriers to trade and FDI (broadly defined) on economic growth, not welfare analysis.

[7] Even if those regulations also affect domestic producers, they can overcome them more easily given their deeper knowledge of the domestic market.

any xed costs when producing for the domestic nal good sector (or that $_d = 0$ for domestic production). The lack of xed costs for both domestic producers and exporters allows me to focus on the e ects of the trade-o between the variable costs of trade and the xed costs of FDI.

If the costs of exporting to country F are high (Figure 1), rm H cannot win in the foreign market by exporting. It could win by doing FDI if the variable pro t made in that market (an increasing function of the technology gap) is enough to compensate the xed cost of FDI. If not, the high barriers to trade and FDI will allow rm F to capture its domestic market.

If trade costs to access market F are su ciently low (Figure 2), then rm H has lower unit costs whether it exports or does FDI. So, even if FDI costs are very high, it will capture market F via exports. If FDI costs are low enough, it will capture it via FDI instead. If trade and FDI costs are such that rm H is indi erent between the two options, I assume it chooses to produce at home and export to the foreign country.

Finally, if trade costs are such that rm H's total unit cost of exports exactly matches MC_F (Figure 3), then rm H could at best tie with rm F by exporting. If FDI costs are too high, then I assume rm F captures its domestic market but makes zero pro ts (because of the threat of rm H

$$[p_H \quad MC_F]X_H = K_H \ , \quad p_H = \frac{MC_F}{1 \quad _H} \tag{12}$$

So, if FDI costs are low relative to trade costs, rm H will charge the price given in (12). From (8), the quantity produced by rm H will be $X_H = \frac{Y_H}{MC_F}(1 \quad _H)$. Firm H's pro ts in this case will be

$$_{HH} = 1 \quad (1 \quad _H) \quad ^n \quad Y_H ; \tag{13}$$

and $_{FH} = 0$

and 4 in Table 2). For very high FDI costs ($_F$ 1 $\frac{1}{_F}$), the price charged by rm F is determined by the threat of rm H exporting. For intermediate FDI costs, $_F$ 2 [1 ^{n}; 1 $\frac{1}{_F}$), the threat of FDI dictates what price rm F charges. The price, output and pro t expressions are analogous to those in the Market H analysis, but reversing the roles of the subscripts H and F, and noticing that rm F makes higher pro ts when

The function ( ) is twice-continuously di erentiable and has the following properties: 1) (0) = 0 (no R&D, no innovation); 2) ^{0}(e) > 0 for e 2 [0; e) (higher productivity-adjusted R&D, up to a certain level, increases the probability of innovation); 3) ^{0}(e) = 0 for e 2 [e; 1) (spending e or more doesn't increase the probability of innovation); and 4) ^{00}(e) < 0 for e 2 [0; e) (diminishing returns to R&D).

From (15), the R&D expenditures required to reach a certain innovation rate are given by the function

$$R_i(j;t) = \;^{1}(z_i(j;t))\,Y_i(t) = (\; z_i(j;t))\,Y_i(t); \qquad (16)$$

where ( ) = ^{1}( ). From the properties of ( ), the function ( ) is characterized by the following properties:

1) e(3)9.9626 Tf 37/F7 6.9738 Tf 6.227 Td[(d [(()]TJ/F11 9.9626 Tf 3.874 0 Td [(e)]TJ/F8 9.9626 Tf 4.639 0 Td [([(i)]TJ/F8

analysis simpler. From now on, I drop all the intermediate industry indices j and identify all the rm- and industry-level variables with the corresponding technology gap n. For example, at the rm level, $z_H^n(t)$ denotes the innovation rate of rm H at time t in an industry with technology gap n. At the industry level, $p_i^n(t)$ denotes the price charged by the winner of the competition for market i at time t in an industry with technology gap n.

DEFINITION (Allocation) . Given the levels of trade and FDI costs ($_H$, $_F$, $_H$, $_F$), an allocation is de ned as a list of pricing, production, and innovation decisions ($p_i^n(t)$, X^n

rm via exports, or the foreign rm via FDI. As can be seen from (23), the cost for domestic producers is based on technology alone, while the cost for foreign producers also involves either variable trade costs or xed costs, depending on whether they capture market i with exports or FDI.

Net exports are given by the negative of net repatriated pro ts from serving the foreign market,

$NX_i(t$

$$Y_i(t) = C_i(t) + R_i(t) + M_i(t) + NX_i(t) \tag{30}$$

Substituting (19) into the nal output production function (4) and rearranging yields equilibrium nal output in country i:

$$Y_i(t) = A_i L_i^{\overline{1}} [Q_i(t)]^{\overline{1}} [\;_i(t;\;_i;\;_i)]^{\overline{1}}; \tag{31}$$

where $Q_i(t)$ and $\;_i(t;\;_i;\;_i)$ are de ned such that

$$\ln(Q_i(t)) \quad \int_0^1 \ln(q_i(j;t))\,dj; \tag{32}$$

and

$$\ln(\;_i(t;\;_i;\;_i)) \quad \sum_{n=\;1}^{1} \;_n(t)\ln(\;_i(n;\;_i;\;_i)) \tag{33}$$

$Q_i(t)$ is an index of the technology of all the domestic intermediate good rms, while $\;_i(t;\;_i;\;_i)$ is a weighted average of the competition regime indices of industries at di erent technology gaps. In general, the latter varies over time because it depends on the proportions $\;_n(t)$, which vary with the innovation rates of all rms as described in the previous section.

2.5.2 Steady-State Equilibrium

For the rest of the paper I focus on steady-state equilibria where aggregate variables grow at constant rates and the international distribution of industries over technology gaps is stationary, so that $\;_n(t) = \;_n$ is constant over time. The latter implies that the aggregate indices of competition, $\;_i(t;\;_i;\;_i)$, are constant over time. Thus,

$$g_i^Y \quad \frac{\dot{Y}_i}{Y_i} = \frac{}{1}\frac{\dot{Q}_i}{Q_i}; \tag{34}$$

where g_i^Y denotes the growth rate of nal output in country i. Since growth of nal output depends only on the evolution of the technology index of domestic rms, $Q_i(t)$, in general the two countries could grow at di erent rates. The following proposition rules out that possibility.

PROPOSITION 1 (Equality of Growth Rates) . Given a stationary distribution of industries across technology gaps, so that $\;_n(t) = \;_n$ is constant over time for all $n \; 2 \; Z$

The intuition behind this result comes from the process of international competition in each industry. As discussed above, the output of each intermediate good sold in a particular country depends on the price chosen by the winner of the competition in that market. If the winner is the domestic rm, the price charged will depend on the marginal production cost and hence the technology of the foreign rm. If the foreign rm is the winner, the price that rm charges will be equal to the marginal production cost of the domestic rm. But the latter can be interpreted as a function of the marginal cost of the foreign rm and the technology gap between them. Thus, the nal output produced with all the intermediate inputs depends on the level of foreign technology and the distribution of industries across technology gaps. But since the latter is assumed to be stationary, nal output growth depends only on the evolution of foreign technology. Since, from (34), nal output growth in the foreign country depends on the evolution of that same technology index, growth in both countries must be equal. It is remarkable that this happens even in the absence of any technological spillovers in the intermediate goods sector. The next proposition establishes what the growth rate of nal output equals to.

Notice that interest rates are equalized across countries even in the absence of international trade in assets. This is entirely driven by the process of international competition that equalizes the growth rates of nal output.

The innovation rates of firms in industries with a given technology gap n are chosen to maximize the net present discounted value of lifetime profits (net of R&D costs). The value of the firms competing in an industry with technology gap n can be written as (see Appendix B)

$$r\, V_H^n(t) \quad V_H^n(t) = \max_{z_H^n(t) \quad 0} \left\{ \quad {}^{n}_{HH}(t) + \quad {}^{n} \right.$$

$$v_F^n = \max_{z_F^n \quad 0} \begin{Bmatrix} {}^{n}_{FF} + {}^{n}_{FH}\,! \quad (z_F^n) \\ + z_H^n \;\; v_F^{n+1} \quad v_F^n \\ + z_F^n \;\; v_F^{n \;\; 1} \quad v_F^n \end{Bmatrix} ; \qquad (41)$$

where ${}^{n}_{id}$ ${}^{n}_{id}(t)=Y_d(t)$ denote pro ts per unit of nal output in market d, and ! $Y_H(t)=Y_F(t)$. Since nal output grows at the same rate in both countries, ! is constant over time in steady-state. The rst-order conditions of the right-hand side problems in (40) and (41) imply the following innovation rates:

$$z_H^n = \max \left\{ 0; \;\; {}^{0 \;\; 1}(v_H^{n+1} \quad v_H^n) \right\} \qquad (42)$$

$$z_F^n = \max \left\{ 0; \;\; {}^{0 \;\; 1}(v_F^{n \;\; 1} \quad v_F^n) \right\} \qquad (43)$$

Since ${}^{00}(z) > 0$ (convexity of the R&D cost function), the innovation rates are increasing in the incremental value of a successful innovation (higher n for rm H, lower for rm F). The max operator takes care of the fact that for very high technology leads, the incremental value of additional innovations gets smaller and smaller and eventually is equal to zero. In that case, leaders choose zero innovation rates.

The innovation intensities determine the entry and exit ows of industries in and out of a given state n. Since the steady-state distribution of industries over technology gaps is stationary, entry and exit ows must o set each other so that ${}_n(t) = {}_n$ for all t. This is shown by the following equation:

$$(z_H^n + z_F^n) \;{}_n = z_H^{n \;\; 1} \;{}_{n \;\; 1} + z_F^{n+1} \;{}_{n+1} \qquad 8n \; 2 \; Z \qquad (44)$$

There is one such equation for each state (technology gap). An industry with technology gap n will ow out of that state at the ow rate $z_H^n + z_F^n$ since either rm H or rm F can make a successful innovation. Since there is a proportion of ${}_n$ industries with technology gap n, exit ows are given by the left-hand side of (44). Entry ows into state n are given in the right-hand side of (44) and can happen from either state $n \;\; 1$ (if rm H innovates), or from state $n+1$ (if rm F innovates). Given the innovation rates from equations (42) and (43), values satisfy (40)-(41); 2) the industry proportions $_n$ are uniquely determined by equations (18) and (44) for all n 2 Z; 3) nal output (and all aggregate variables) in both countries grow at the constant rate given by (35); 4) the interest rate is the same across countries and given by (36); and (5) $Y_H(t)=Y_F(t)$ is constant over time.

The next section provides a numerical solution for the steady-state equilibrium of the model.

3 Quantitative Analysis

3.1 From the Model to Numerical Analysis

To solve the model of the previous section numerically, I make some adjustments that I describe in what follows. First, as in Acemoglu and Akcigit (2012), the numerical solution relies on a uniformization procedure

those barriers. While those transitions are interesting and important, they go beyond the scope of this paper, whose focus is on long-run economic growth.

Figure 5 in Appendix A shows graphically the e ect of bilateral changes in trade and FDI barriers on the common rate of economic growth. In the graph, $_H$ = $_F$ = 2 $[1; 3]$ while $_H$ = $_F$ = 2 $[0; 1]$. Fixing FDI barriers to its highest level of 1, the graph shows that moving from autarky ($= 3$) to free trade ($= 1$) increases the rate of economic growth from 1.79% to 1.94%, which is a sizable increase if sustained for long periods of time. However, the growth rate reaches a maximum of 2.33% (for high FDI barriers) when $= 1{:}33$, not in free trade. Similarly, xing trade barriers at its maximum and allowing FDI costs to vary, we can see that moving from $= 1$ to $= 0$ also increases the growth rate from 1.79% to 1.94%. Again, the maximum growth rate is not reached for the lowest level of barriers, but for $= 0{:}25$, when the growth rate is again 2.33%. This suggests that when only one mode of accessing foreign markets (either exports or FDI) is available, reducing barriers to that available mode from an autarky position to free trade/FDI increases economic growth, but retaining some (relatively small) barriers yields the maximum growth rate.

What if there are no barriers to FDI in the rst place? That is, suppose that FDI barriers are xed at $= 0$, and trade barriers are reduced from autarky to free trade. In that case, the rate of economic growth remains constant at 1.94%. This is because, no matter how low the trade barriers get, the absence of barriers to FDI makes the latter the most pro table option for competing in the foreign market for technological leaders, and the most credible threat of undercutting for technological followers. The same result is achieved if there

to a moderate level still leaves FDI as the more pro table way of serving the foreign market, so neither the incentives to innovate nor the distribution of industries is a ected by that reduction in trade barriers. That in Figure 13. Moving towards autarky decreases competition in market H and increases it in market F. As a result of that, $!$ decreases, and pro ts in foreign markets become higher for H rms and smaller for F rms. This is a relative-market-size e ect. Figures 14-15 show that this gives higher incentives to innovate to H rms and lower incentives to F rms, which explains why in Figure 16 the distribution of industries shifts towards higher concentration on industries with H leaders. This is consistent with the decrease in competition in market H and the increase in market F.

The movement towards free trade has the opposite e ects on the competition indices and $!$. But these e ects have a higher magnitude now, so innovation incentives are much higher now for F rms and much lower for H

to yield a more balanced distribution of industries in terms of competition and innovation incentives, which results in higher growth. Finally, maintaining high barriers to trade and FDI retains the property of having a more uniform distribution of industries, but with much lower innovation incentives and growth.

The results of the unilateral experiments with otherwise symmetric countries also suggest that moderate barriers are growth maximizing. But in this case, the relative-market-size effect has to be taken into account. A unilateral change in trade barriers, deviating from a scenario with symmetric barriers for both trade and FDI, makes one market more competitive than the other, leading to higher output in the more competitive market, and generating asymmetric incentives for innovation for firms in different countries. This biases the distribution of industries in a way that most industries are dominated by the firms of the country whose market is less competitive. For example, when country H unilaterally raises trade barriers, market F becomes more competitive than market H, increasing final output in the former, and lowering final output in the latter. The higher relative demand in market F, together with the high barriers to access market H, gives higher innovation incentives to H firms, which end up having large technological advantages in a high share of intermediate good industries. This lowers economic growth in both countries.

The excessive-competition and relative-market-size effects reinforce each other to lower economic growth when the unilateral move is towards free trade. In that case, the country that lowers its trade barriers ends up having a more competitive market relative to the other country. This lowers the incentives to innovate of the firms from the liberalizing country and increases the incentives of the firms in the other country, which end up being the technological leaders for many industries. This is the relative-market-size effect at play. But because free trade makes technological differences the only determinant of innovation incentives, the lower trade barriers introduce so much competition that the share of industries dominated by the country that did not change its trade barriers is much higher than the share captured by the other country when it moves towards autarky. Since firms with high technological leads innovate very little, growth decreases more when trade barriers are very low.

4 Alternative Specifications

In this section I perform additional experiments with alternative specifications of the model. First, I perform experiments in which country H has a higher population size than country F. Second, I make the parameter that controls the size of innovations ( ) higher or lower to see how that affects the results of the previous section. Finally, I allow for a larger range of technology gaps, so that firms with 3-step leads choose positive innovation rates. To simplify the analysis, for all the specifications I focus on bilateral experiments only. I conclude this section with a discussion of the robustness of the model to these alternative specifications.

4.1 Di erent Population Size Across Countries

The baseline speci cation assumed symmetry in terms of all parameters of the model, including population size. But the results of the baseline unilateral experiments suggest that introducing asymmetries in the model will give rise to the relative-market-size e ect. I test that idea in this section.

4.4 Discussion

The baseline experiments showed the importance of considering both trade and FDI barriers when analyzing the e ects of trade or FDI liberalization on economic growth. The main mechanisms at work were the excessive-competition and relative-market-size e ects. The numerical analysis under alternative speci cations in terms of asymmetries in population size, higher or lower size of innovations, and a higher range of technology gaps, suggests that those mechanisms are relatively robust to these alternative speci cations of the model. However, while the qualitative patterns seem to hold well, the quantitative e ects of di erent trade and FDI barriers on economic growth are somewhat sensitive to these speci cations.

While giving precise quantitative answers is important to understand the e ects of globalization, the goal of this paper is not to provide such precise measures of the e ects of trade and FDI barriers on economic growth, but to call attention to the fact that models that only allow for trade as the only form of accessing foreign markets can provide a wrong assessment of the e ects of trade liberalization on economic growth that take place via the competition channel. As shown in the previous sections, those e ects can be very di erent depending on the size of barriers to FDI.

The analysis also points out the importance of measuring the size of trade and FDI barriers in each country, to make a better assessment of policies directed at changing those barriers with the goal of making economic growth as high as possible. This is especially relevant nowadays that there seems to be a resurgence of protectionism in high-income countries.

5 Concluding Remarks

In this paper I have developed a model of endogenous growth to assess the role of trade and horizontal FDI among high-income countries in shaping long-run growth, with a focus on the e ects of trade and FDI barriers on the degree of competition in each market. The model highlights the importance of considering both modes of accessing foreign markets when analyzing trade or investment liberalization policies.

When barriers to FDI are very high, bilateral movements towards free trade yield higher growth than autarky, but moderate barriers to trade are growth maximizing. The decrease in growth from a situation with moderate barriers to free trade is explained by an excessive-competition e ect whereby very high innovation rates in neck-and-neck industries and low innovation rates in industries of the leader-and-follower type yield an equilibrium

Unilateral changes in trade barriers in similar countries, or bilateral changes in countries of different size, give rise to a relative-market-size effect that makes countries asymmetric in terms of the degree of competition and shifts the distribution of industries so that the firms from one country become technological leaders with high advantages over their rivals for most products. Since these kinds of firms have lower incentives for innovation, economic growth tends to decrease as a result of the unilateral change in barriers.

While these qualitative patterns are consistent across different specifications, the model's quantitative results are somewthat sensitive to different parameter values. This suggests it is important to have good, structural measures or estimates of the elements captured by those parameters, such as the size of innovations by different firms, to give an accurate assessment of the quantitative effects of globalization on economic growth. This model just provides a first step in the analysis of trade and FDI barriers and their effects on economic growth via changes in competition.

The model also makes a few assumptions that make the analysis more tractable. For example, the fixed costs of FDI are assumed to be non-sunk, which makes the profit analysis static. Relaxing that assumption would give richer interactions between the exports-versus-FDI trade-off and innovation decisions. This is an interesting avenue for further research.

References

Acemoglu, D., and U. Akcigit (2012). Intellectual Property Rights Policy, Competition and Innovation. Journal of the European Economic Association 10(1), 1-42.

Aghion, P., N. Bloom, R. Blundell, R. Gri th, and P. Howitt (2005). Competition and Innovation: An Inverted-U Relationship. Quarterly Journal of Economics, 120, 701-728.

Aghion, P., R. Blundell, R. Gri th, P. Howitt, and S. Prantl (2009). The E ects of Entry on Incumbent Innovation and Productivity. Review of Economics and Statistics, 91(1), 20-32.

Aghion, P., and R. Gri th (2005). Competition and Growth: Reconciling Theory and Evidence. MIT Press, Cambridge, MA.

Aghion, P., C. Harris and J. Vickers (1997). Competition and Growth with Step-by-Step Innovation: An Example. EuropeanC [(R)51(evi,cs)]TJ/F15 9.9626 Tf26.29536 0 Td 4051,

Aghion,31005(P)83(.,31005(C.30471(Harr(.,31196(P)84(.3-504(Ho)28(witt,31007(and)-50J(C.30471(Vic)28(k)28

Journa-3-358(of)-877conomics

[illegible]

Working Papers on International Investment, 2010/03, OECD Publishing, Paris.

Appendix A: Figures and Tables

Model Figures and Tables

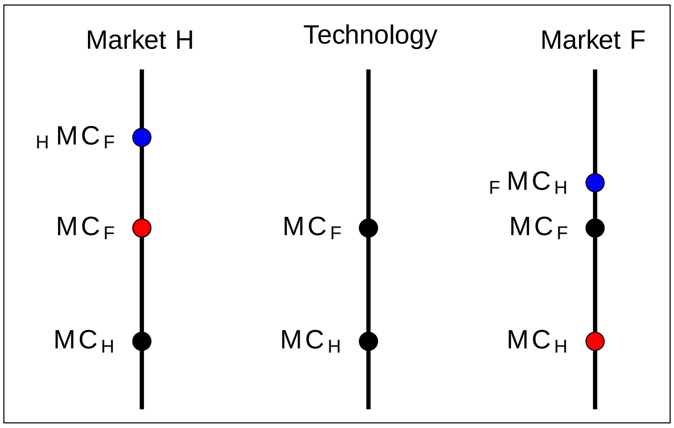

Figure 1: H Leader, High $_F$

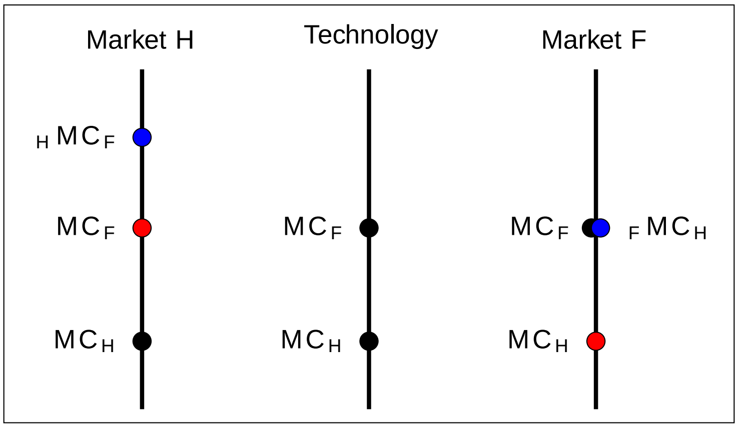

Figure 3: H Leader, Intermediate F

Notes: The vertical line in the center represents marginal costs for rms H and F

Table 1: H Leader, Market H

Table 3: F Leader, Market F

	High FDI Cost	Low FDI Cost
	$_F$ 1 1= $_F$	$_F$ < 1 1= $_F$
Winner	Firm F	Firm F
p_F	$_F MC_H$	$\frac{MC_H}{1 \quad _F}$
X_F	$\frac{Y_F}{_F MC_H}$	$\frac{Y_F}{MC_H}(1 \quad _F)$
$_{FF}$	$\left[1 \quad \frac{1}{_F} \quad ^n\right] Y_F$	$[1 \quad (1 \quad _F) \quad ^n] Y_F$
$_{HF}$	0	0

Notes: The table represents the di erent competition regimes that can exist in market F when rm F is the technological leader (n < 0), for di erent combinations of trade and FDI costs to access that market. For each combination, the table speci es the winner of the competition, the price charged and the output produced by the winner, and the pro ts made by each rm in that market.

Table 4: F Leader, Market H

	Low Trade Cost $_H$ < ^{n}		High Trade Cost $_H$ ^{n}		
	High FDI Cost $_H$ [$_H$ 1] ^{n}	Low FDI Cost $_H$ < [$_H$ 1] ^{n}	High FDI Cost $_H$ 1 $\frac{1}{_H}$	Medium FDI Cost $_H$ 2 [1 ^{n}; 1 $\frac{1}{_H}$)	Low FDI Cost $_H$ < 1 ^{n}
Winner	Firm F (Exports)	Firm F (FDI)	Firm H	Firm H	Firm F (FDI)
p_H	MC_H	MC_H	$_H MC_F$	$\frac{MC_F}{(1 \quad _H)}$	MC_H
X_H	$\frac{Y_H}{MC_H}$	$\frac{Y_H}{MC_H}$	$\frac{Y_H}{_H MC_F}$	$\frac{Y_H}{MC_F}(1 \quad _H)$	$\frac{Y_H}{MC_H}$
$_{FH}$	$[1 \quad _H \quad ^n] Y_H$	$[1 \quad ^n$			

Numerical Analysis

Table 5: Baseline Parameter values

Parameter	Value	Parameter	Value
	0.3		1.1
	0.05		0.3
A_H	1		2.07
A_F	1	z	1
L_H	1	$_H = _F$	1.11
L_F	1	$_H = _F$	1

Notes: The table provides the parameter values used in the baseline experiments. See the main text for an explanation of each value.

Figure 5: Trade/FDI Costs and Economic Growth: Bilateral

Notes: The gure represents the rate of economic growth in both countries for di erent combinations of trade and FDI costs in the baseline speci cation. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

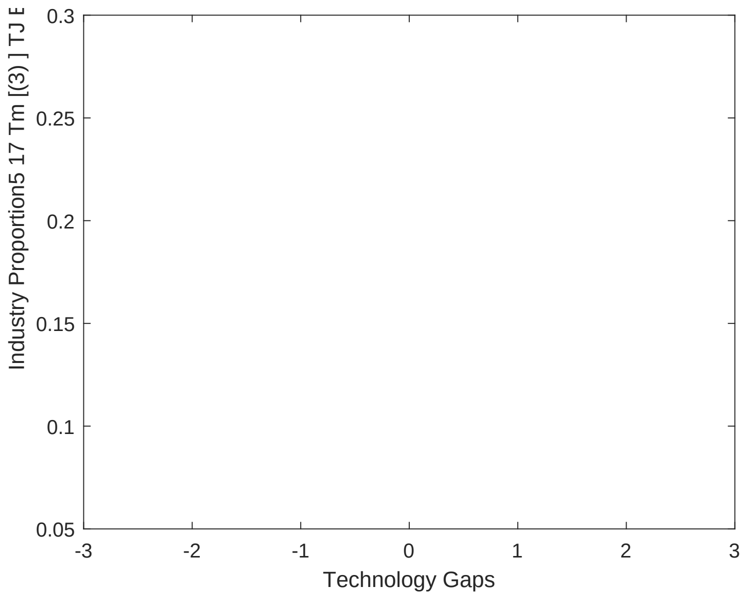

Figure 6: Trade Costs and Industry Distributions: Bilateral (= 1)

Notes: The gure represents the proportions of industries at di erent technology gaps in the baseline bilateral speci cation for $_H$ = $_F$ = 1 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

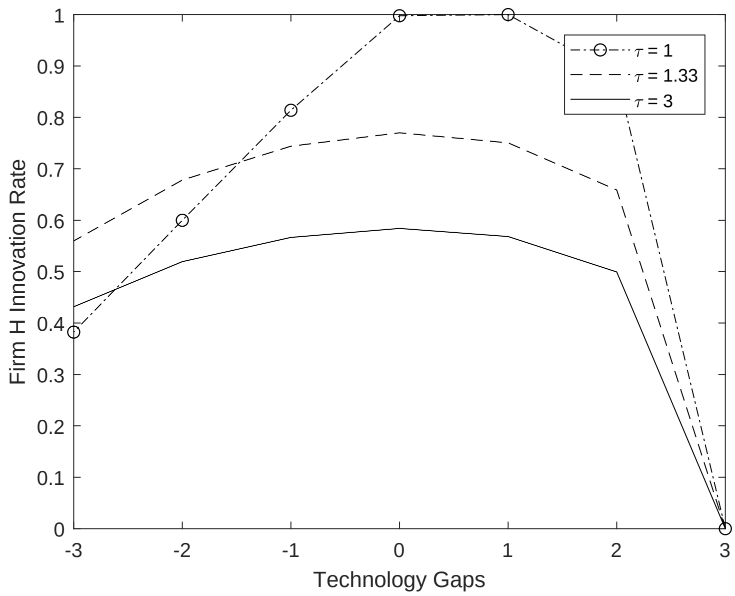

Figure 7: Trade Costs and Firm H 's Innovation Rates: Bilateral (= 1)

Notes: The gure represents the innovation rates of rms from country H in industries at di erent technology gaps in the baseline bilateral speci cation for $_H$ = $_F$ = 1 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

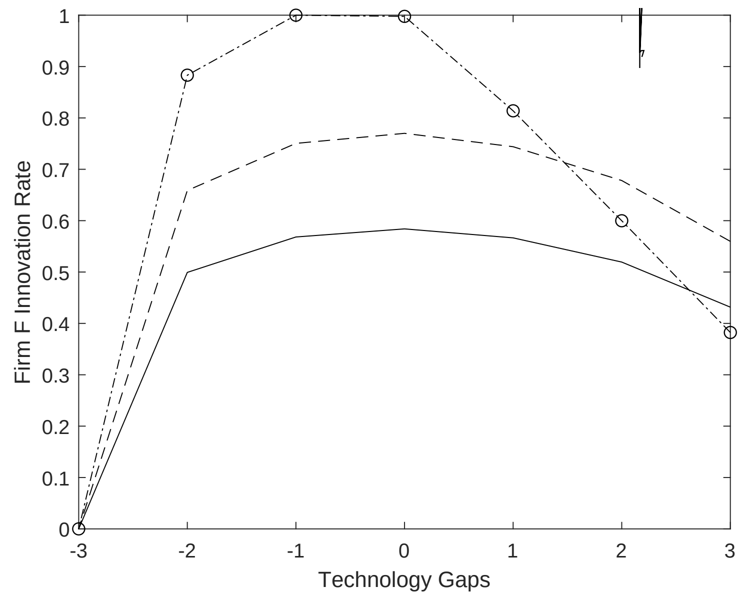

Figure 8: Trade Costs and Firm F's Innovation Rates: Bilateral (= 1)

Notes: The gure represents the innovation rates of rms from country F in industries at di erent technology gaps in the baseline bilateral speci cation for $_H$ = $_F$ = 1 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

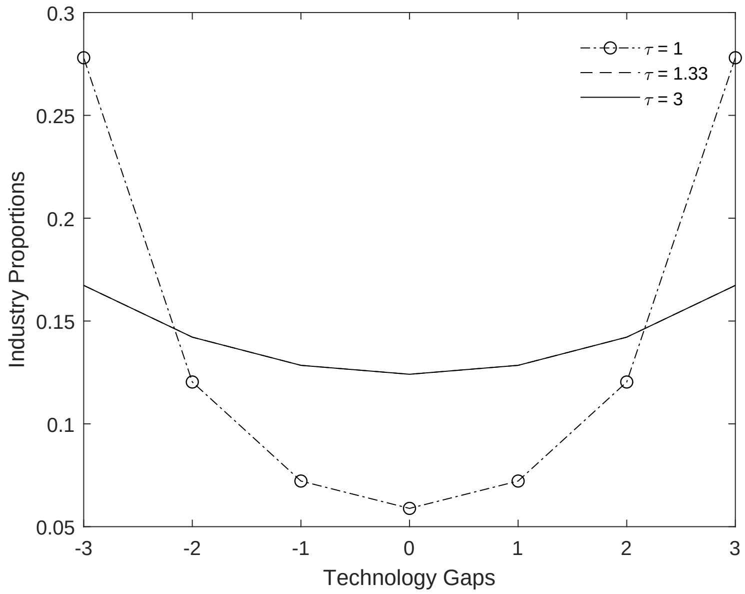

Figure 9: Trade Costs and Industry Distributions: Bilateral (= 0:25)

Notes: The gure represents the proportions of industries at di erent technology gaps in the baseline bilateral speci cation for $_H$ = $_F$ = 0:25 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

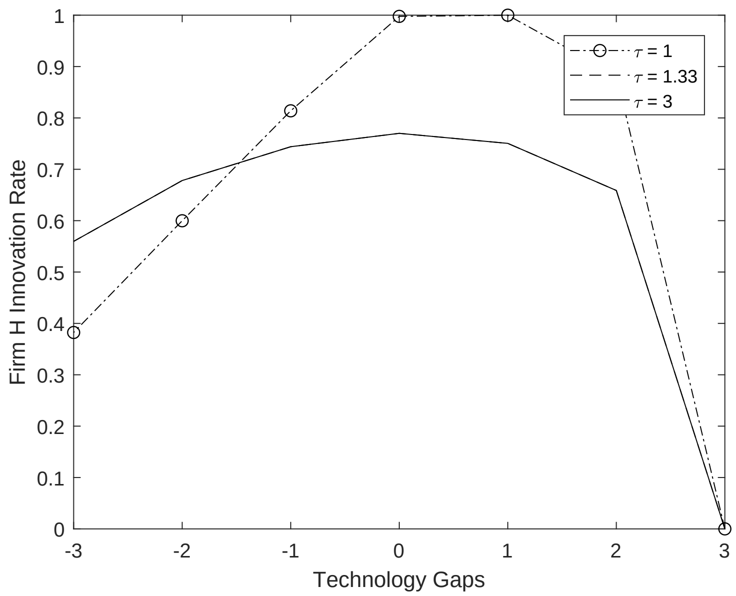

Figure 10: Trade Costs and Firm H 's Innovation Rates: Bilateral (= 0:25)

Notes: The gure represents the innovation rates of rms from country H in industries at di erent technology gaps in the baseline bilateral speci cation for $_H$ = $_F$ = 0:25 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

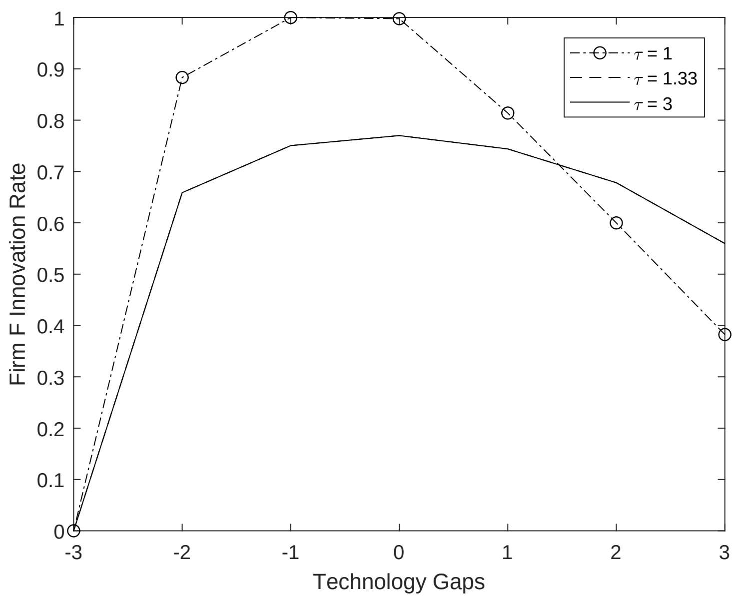

Figure 11: Trade Costs and Firm F 's Innovation Rates: Bilateral (= 0:25)

Notes: The gure represents the innovation rates of rms from country F in industries at di erent technology gaps in the baseline bilateral speci cation for $_H$ = $_F$ = 0:25 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model.

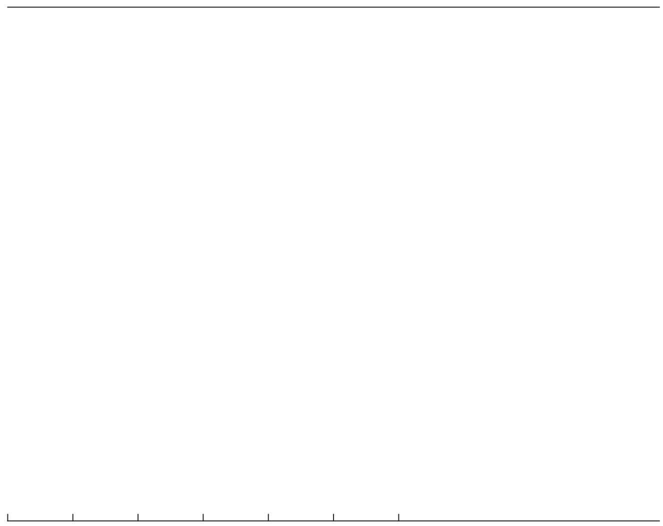

Figure 12: Trade Costs in H and Economic Growth: Unilateral

Notes: The gure represents the rate of economic growth in both countries for di erent values of trade costs in country H. Trade costs in country F are xed at the baseline level of 1.11. FDI costs are xed (in both countries) at a level of 0.1. The two countries are symmetric in every other parameter of the model (baseline values).

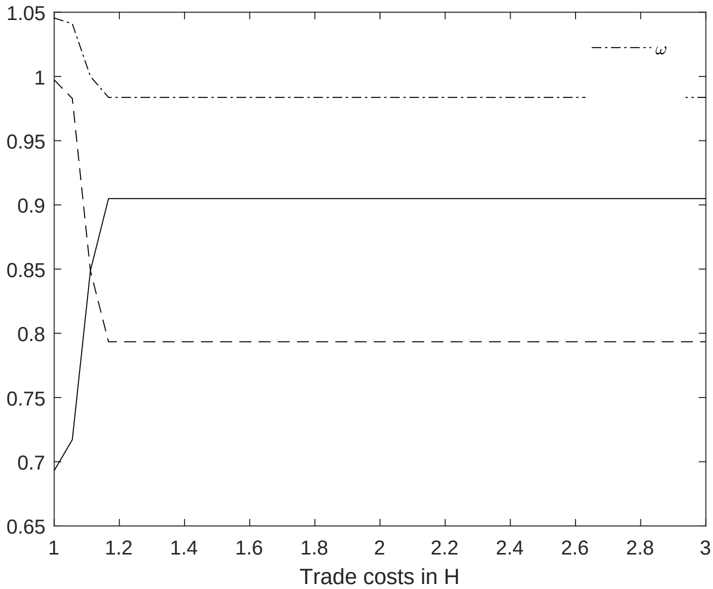

Figure 13: Trade Costs in H, Omega Ratio, and Competition Indices: Unilateral

Notes: The gure represents the ratio of nal outputs $! = Y_H = Y_F$ and aggregate competition indices in both countries for di erent values of trade costs in country H. Trade costs in country F are xed at the baseline level of 1.11. FDI costs are xed (in both countries) at a level of 0.1. The two countries are symmetric in every other parameter of the model (baseline values).

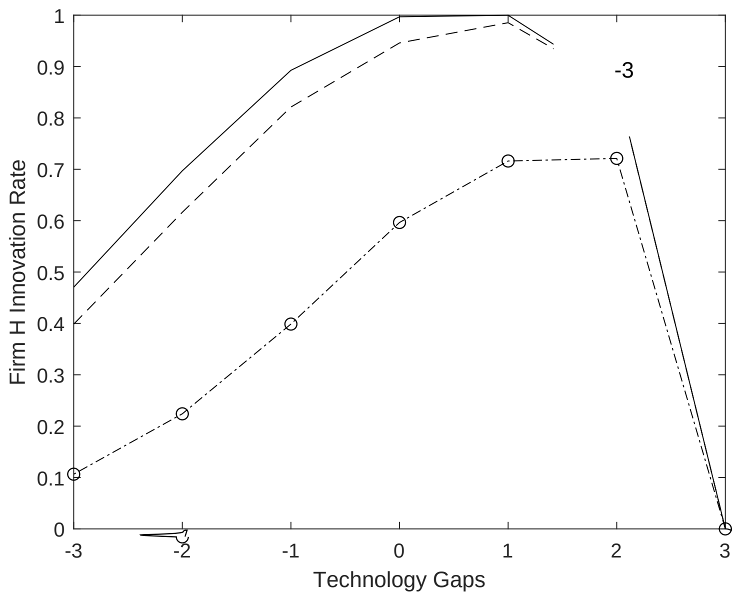

Figure 14: Trade Costs in H and Firm H's Innovation Rates: Unilateral

Notes: The gure represents the innovation rates of rms from country H in industries at di erent technology gaps for di erent values of trade costs in country H. Trade costs in country F are xed at the baseline level of 1.11. FDI costs are xed (in both countries) at a level of 0.1. The two countries are symmetric in every other parameter of the model (baseline values).

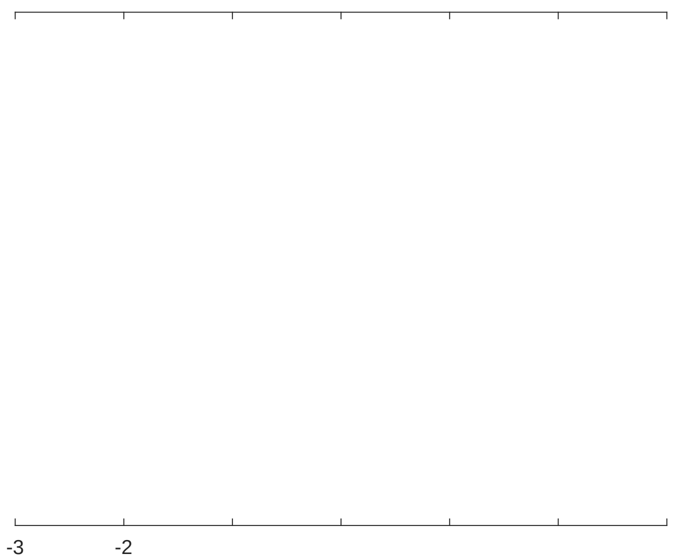

Figure 15: Trade Costs in H and Firm F's Innovation Rates: Unilateral

Notes: The gure represents the innovation rates of rms from country F in industries at di erent technology gaps for di erent values of trade costs in country H. Trade costs in country F are xed at the baseline level of 1.11. FDI costs are xed (in both countries) at a level of 0.1. The two countries are symmetric in every other parameter of the model (baseline values).

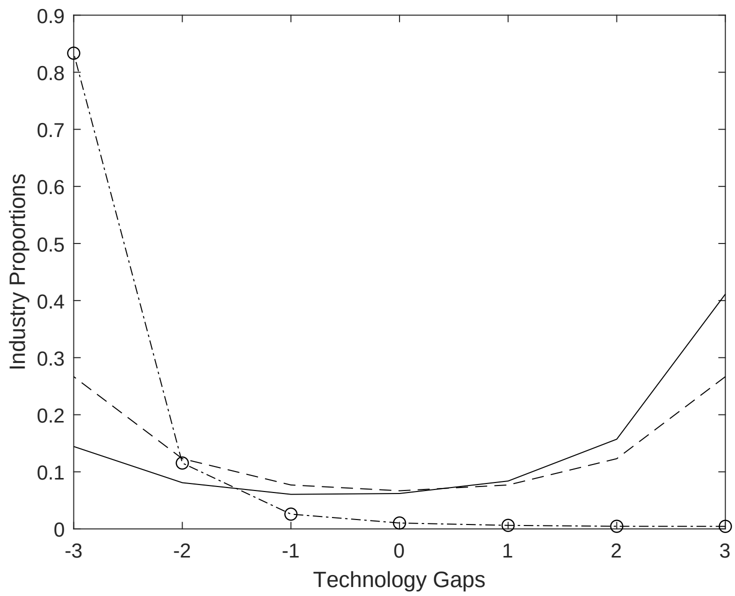

Figure 16: Trade Costs in H and Industry Distributions: Unilateral

Notes: The gure represents the proportions of industries at di erent technology gaps for di erent values of trade costs in country H. Trade costs in country F are xed at the baseline level of 1.11. FDI costs are xed (in both countries) at a level of 0.1. The two countries are symmetric in every other parameter of the model (baseline values).

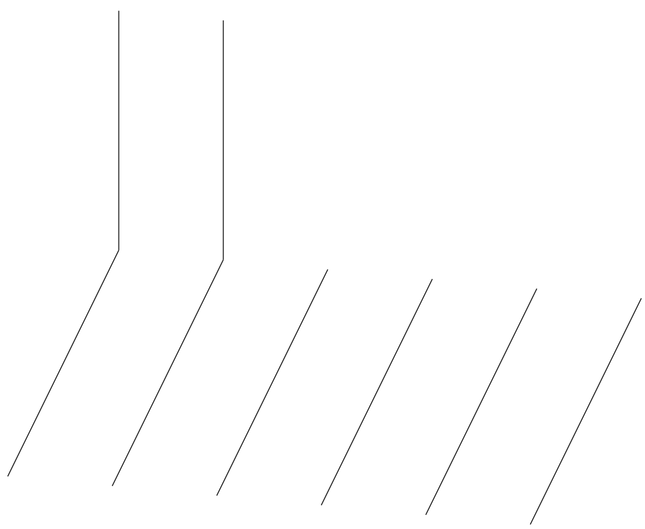

Figure 17: Trade/FDI Costs and Economic Growth: Bilateral ($L_H = 2$)

Notes: The gure represents the rate of economic growth in both countries for di erent combinations of trade and FDI costs. The two countries are symmetric in terms of trade and FDI costs, but country H has twice as much population as country F. The two countries are symmetric in terms of all other parameters (baseline values).

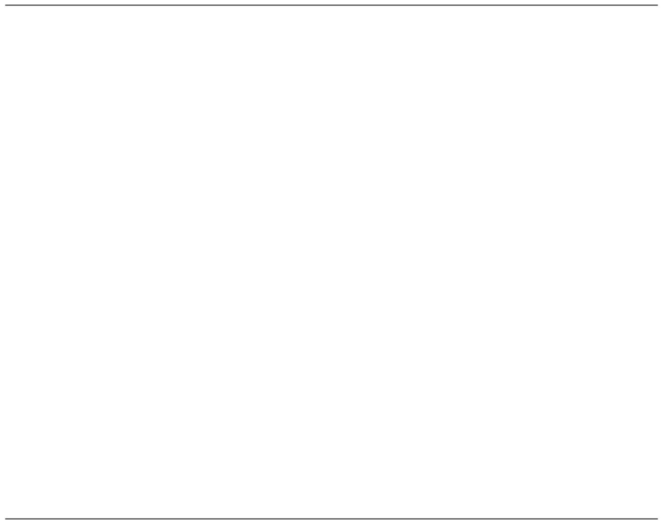

Figure 18: Trade Costs, Omega Ratio, and Competition Indices: Bilateral ($L_H = 2$)

Notes: The figure represents the ratio of final outputs $\omega = Y_H/Y_F$ and aggregate competition indices in both countries for $_H = {}_F = 1$ and three different levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, but country H has twice as much population as country F. The two countries are symmetric in terms of all other parameters (baseline values).

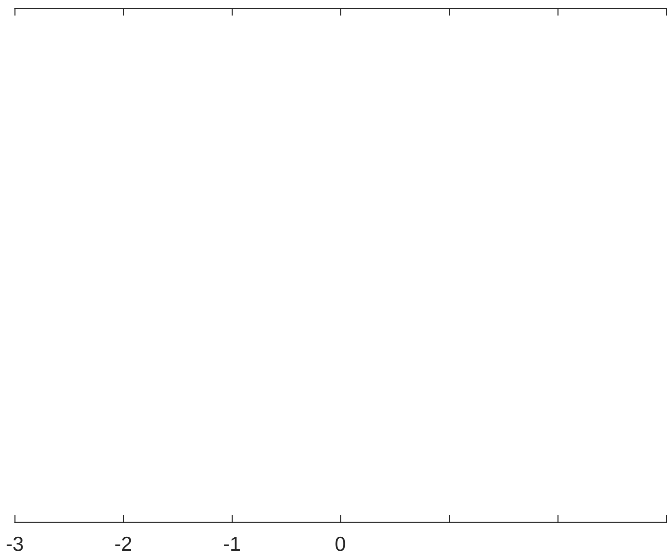

Figure 19: Trade Costs and Industry Proportions: Bilateral ($L_H = 2$)

Notes: The figure represents the proportions of industries at different technology gaps for $_H = {}_F = 1$ and three different levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, but country H has twice as much population as country F. The two countries are symmetric in terms of all other parameters (baseline values).

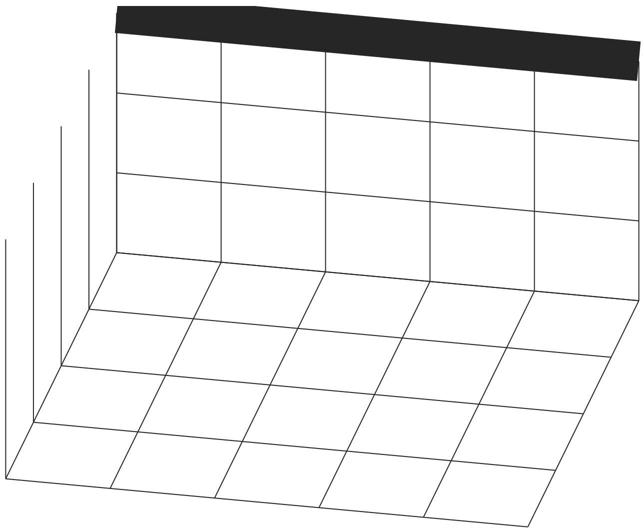

Figure 20: Trade/FDI Costs and Economic Growth: Bilateral (= 1:05)

Notes: The gure represents the rate of economic growth in both countries for di erent combinations of trade and FDI costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model (baseline values), but the size of innovations is set to = 1:05.

Figure 21: Trade/FDI Costs and Economic Growth: Bilateral (= 1:15)

Notes: The gure represents the rate of economic growth in both countries for di erent combinations of trade and FDI costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model (baseline values), but the size of innovations is set to = 1:15.

Figure 22: Trade Costs and Industry Distributions: Bilateral ($= 1{:}05$)

Notes: The gure represents the proportions of industries at di erent technology gaps for $_{H} = {}_{F} = 1$ and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model (baseline values), but the size of innovations is set to $= 1{:}05$.

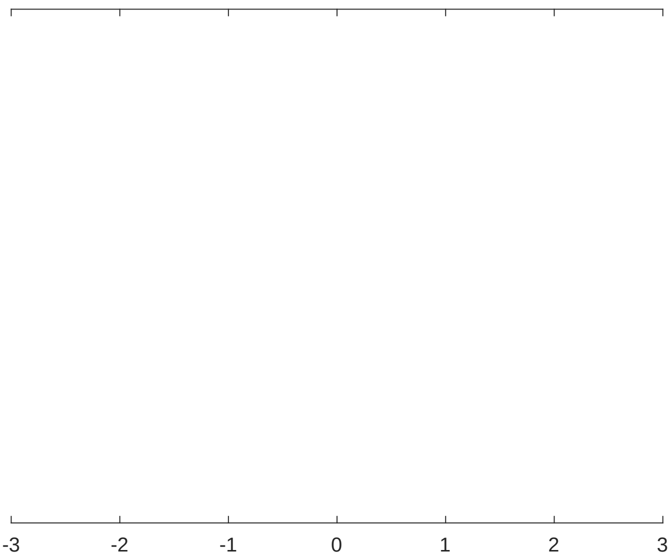

Figure 23: Trade Costs and Industry Distributions: Bilateral ($= 1{:}15$)

Notes: The gure represents the proportions of industries at di erent technology gaps for $_{H} = {}_{F} = 1$ and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model (baseline values), but the size of innovations is set to $= 1{:}15$.

Figure 24: Trade/FDI Costs and Economic Growth: Bilateral (max n = 4)

Notes: The gure represents the rate of economic growth in both countries for di erent combinations of trade and FDI costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model (baseline values), but the maximum technology gap is set to 4.

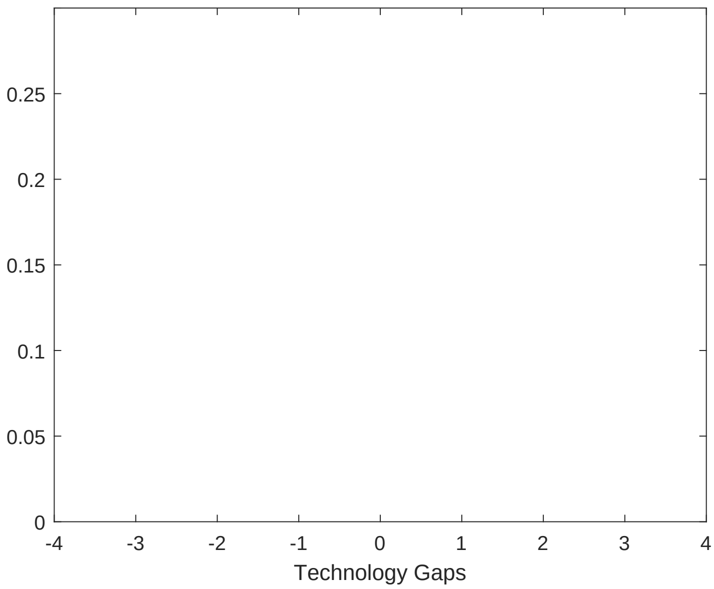

Figure 25: Trade Costs and Industry Distributions: Bilateral (max n = 4)

Notes: The gure represents the proportions of industries at di erent technology gaps for $_H$ = $_F$ = 1 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter of the model (baseline values), but the maximum technology gap is set to 4.

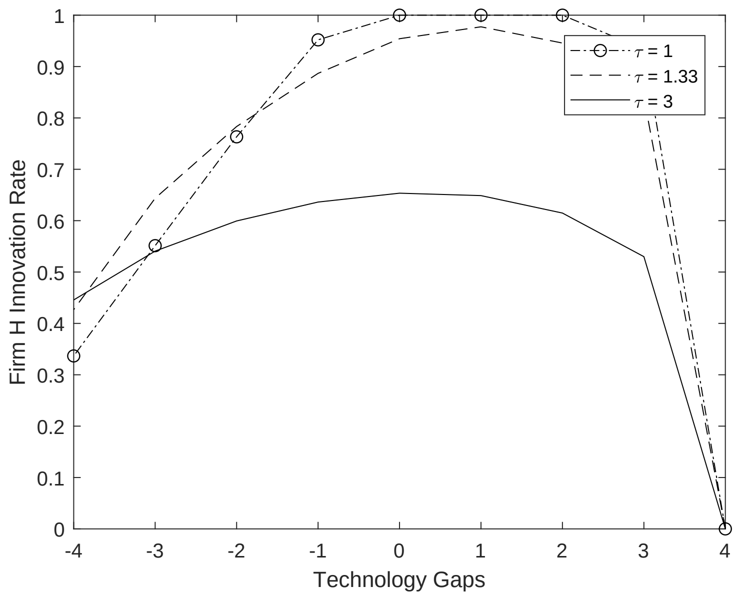

Figure 26: Trade Costs and Firm H 's Innovation Rates: Bilateral (max n = 4)

Notes: The gure represents the innovation rates of rms from country H in industries at di erent technology gaps for $_H$ = $_F$ = 1 and three di erent levels of trade costs. The two countries are symmetric in terms of trade and FDI costs, and every other parameter

$$
\begin{aligned}
{}_{HH} &= [p_H \quad MC_H] X_H = [p_H \quad MC_H] \frac{Y_H}{p_H} \\
&= 1 \quad \frac{MC_H}{p_H} \quad Y_H \\
&= 1 \quad (1 \quad {}_H) \frac{MC_H}{MC_F} \quad Y_H \\
&= 1 \quad (1 \quad {}_H) \quad {}^{n} \; Y_H
\end{aligned}
$$

H leaders, Market F (Table 2)

First, trade costs to access this market are considered low if the unit costs of exporting for rmH are smaller

Otherwise, firm F captures its domestic market. In that case, the price it charges depends on the threat by firm H of undercutting with exports or FDI. This is analogous to the analysis of market H above with the roles of the H and F subscripts reversed.

F leaders (Tables 3 and 4)

The derivations for all the expressions in Tables 3 and 4 mimic the ones for those of Tables 1 and 2, with the roles of H and F reversed.

Aggregate Resource Constraint

In this section I show that the aggregate resource constrain (30) is satisfied in equilibrium. To simplify the notation, I omit the time indices. First, since the final good sector is perfectly competitive, the representative firm makes zero profits. From (5),

$$\begin{aligned} Y_i &= w_i L_i + \int_0^1 p_i(j) X_i(j) dj \\ &= w_i L_i + \sum_{n=1}^{\infty} \mu_n p_i^n X_i^n \end{aligned}$$

Since industries can be dominated by domestic or foreign firms, and revenue (profits plus total costs) is determined by the costs of trade and FDI, the second term on the right-hand side can be written as

$$\begin{aligned} \sum_{n=1}^{\infty} \mu_n p_i^n X_i^n = & \sum_{n=1}^{\infty} \mu_n [\mathbb{1}_i^{DOM} (\pi_{ii}^n + MC_i^n X_i^n) \\ & + \mathbb{1}_i^{EX} ((\pi_{di}^n)^{EX} + \tau_i MC_d^n X_i^n) \\ & + \mathbb{1}_i^{FDI} ((\pi_{di}^n)^{FDI} + MC_d^n X_i^n + K_i)] \\ = & \sum_{n=1}^{\infty} \mu_n [\mathbb{1}_i^{DOM} \pi_{ii}^n + \mathbb{1}_i^{EX} (\pi_{di}^n)^{EX} + \mathbb{1}_i^{FDI} (\pi_{di}^n)^{FDI}] + M_i ; \end{aligned}$$

using the definitions of the total cost of intermediate goods production M_i in (23) and the indicator functions $\mathbb{1}_i^m$, $m \in \{DOM; EX; FDI\}$ in (24)-(26). I omit the arguments of those indicator functions for simplicity. Combining the last two expressions and solving for labor income yields:

$$w_i L_i = Y_i - M_i - \sum_{n=1}^{\infty} \mu_n [\mathbb{1}_i^{DOM} \pi_{ii}^n + \mathbb{1}_i^{EX} (\pi_{di}^n)^{EX} + \mathbb{1}_i^{FDI} (\pi_{di}^n)^{FDI}]$$

Since the representative household effectively owns all the domestic firms, asset income $r_i B_i$ is equal to the total pro ts made by those rms in both markets:

$$r_i B_i = \sum_{n=1}^{1} {}_n[\, {}^{DOM}_{i} \; {}^{n}_{ii} + {}^{EX}_{d} (\; {}^{n}_{id})^{EX} + {}^{FDI}_{d} (\; {}^{n}_{id})^{FDI}]$$

Substituting the expressions for labor and asset income, together with the market clearing condition for assets, $B_i = R_i$, into the budget constraint of the representative household (2) yields:

$$\begin{aligned} R_i &= Y_i \quad M_i \quad \sum_{n=1}^{1} {}_n[\, {}^{EX}_{i} (\; {}^{n}_{di})^{EX} \quad {}^{EX}_{d} (\; {}^{n}_{id})^{EX} + {}^{FDI}_{i} (\; {}^{n}_{di})^{FDI} \quad {}^{FDI}_{d} (\; {}^{n}_{id})^{FDI}] \quad C_i \\ &= Y_i \quad M_i \quad NX_i \quad C_i ; \end{aligned}$$

where the second equality makes use of the de nition of net exports in (27). Rearranging the last equation yields the aggregate resource constraint.

Derivation of Equation (31)

Substituting (19) into the nal output production function yields

$$\begin{aligned} Y_i(t) &= (A_i L_i)^1 \quad \exp \int_0^1 \ln(X_i(j;t))\,dj \\ &= (A_i L_i)^1 \quad \exp \int_0^1 \ln(\; Y_i(t) q_i(j;t) \; {}_i(n(j;t); \; {}_i; \; {}_i))\,dj \\ &= (A_i L_i)^1 \quad \exp(\int_0^1 \ln(\;)\,dj + \int_0^1 \ln(Y_i(t))\,dj \\ &\quad + \int_0^1 \ln(q_i(j;t))\,dj + \int_0^1 \ln(\; {}_i(n(j;t); \; {}_i; \; {}_i))\,dj \end{aligned}$$

Using the de nitions in (32)-(33) for the technology and competition indices, the fact that and $Y_i(t)$ don't depend on j, the fact that the exponential and logarithmic functions are inverses of each other, and solving for $Y_i(t)$ yields (31).

Proof of Proposition 1 (Equality of Growth rates)

From (34) it is clear that output grows at the same rate in both countries if and only if the technology indices $Q_H(t)$ and $Q_F(t)$ grow at the same rate. Here I show this is the case. The index in country F can be written as follows:

$$\ln(Q_F(t)) \quad \int_0^1 \ln(q_F(j;t))\,dj$$
$$= \int_0^1 \ln \quad q_H(j;t) \quad ^{n(j;t)} \quad dj$$
$$= \int_0^1 \ln(q_H(j;t))\,dj \quad \ln(\ ) \int_0^1 n(j;t)\,dj$$
$$= \ln(Q_H(t)) \quad \ln(\ ) \sum_{n=1}^{1} n \quad {}_n(t)$$

Rearranging yields

$$\ln \quad \frac{Q_H(t)}{Q_F(t)} \quad = \ln(\ ) \sum_{n=1}^{1} n \quad {}_n(t)$$

If the distribution of industries over technology gaps is stationary, then the right-hand side of the previous equation is constant over time. That implies the two technology indices, and nal output in both countries, must grow at the same rate.

Proof of Proposition 2 (Steady-State Growth Rate)

In steady state, growth in both countries depends on the evolution of the technology index $Q_H(t)$ (or $Q_F(t)$). For each industry with a technology gap of n, rm H upgrades its technology $q_H^n(t)$ to $q_H^n(t + \quad t) = \quad q_H^n(t)$ with probability $z_H^n \quad t + o(\quad t)$, and fails to do so with probability $1 \quad z_H^n \quad t \quad o(\quad t)$. Thus,

$$\ln(Q_H(t + \quad t)) = \ln(Q_H(t)) + \sum_{n=1}^{1} \quad {}_n(t)(z_H^n \quad t + o(\quad t)) \ln(\ )$$

Subtracting $\ln(Q_H(t))$ from both sides, dividing by t, and taking the limit as $t\ !\ \ 0$; yields the growth rate of $Q_H(t)$:

$$g_H^Q \quad \frac{d\ln(Q_H(t))}{dt} = \ln(\ ) \sum_{n=1}^{1} \quad {}_n z_H^n \quad {}_H$$

)F.1 9.9626 Tf 338 l82r [(H)]reason [( )]shoF11 j; (Q_H (t) ln
190d [(iTd [(dt)]TJ/F8 9.9626 Tf 33.8. 6.834 Td [(=)]TJ/F15 9.9626 Tf 125 18 2[(ln)]TJ/F8 9.9626 Tf 9.9612.7457[( )]TJ/F11 9.9626 Tf 3.8

$$V_H^n(t) = \max_{z_H^n(t) \quad 0} \quad 8 \quad [\quad {}^{n}_{HH}$$

$$(g^Y + \rho)\frac{V_F^n(t)}{Y_F(t)} - \frac{\dot{V}_F^n(t)}{V_F^n(t)}\frac{V_F^n(t)}{Y_F(t)} = \max_{z_F^n(t) \geq 0} \left\{ \begin{array}{l} \frac{\pi_{FF}^n(t)}{Y_F(t)} + \frac{\pi_{FH}^n(t)}{Y_H(t)}\frac{Y_H(t)}{Y_F(t)} - \Gamma(z_F^n(t)) \\ + z_H^n(t)\left[\frac{V_F^{n+1}(t)}{Y_F(t)} - \frac{V_F^n(t)}{Y_F(t)}\right] \\ + z_F^n(t)\left[\frac{V_F^{n-1}(t)}{Y_F(t)} - \frac{V_F^n(t)}{Y_F(t)}\right] \end{array} \right\},$$

Again, using the fact that $V_i^n(t)$ grows at the steady-state rate g^Y, the definitions of stationarized values, profits per unit of final output in the destination market, and the ratio of final outputs ω, yields equation (41).

Numerical Analysis

In this section I describe the uniformization procedure used to adjust the model for the numerical analysis. This is an adaptation of the procedure in Acemoglu and Akcigit (2012), which in turn is based on Ross (1996, pp. 282-284). The goal is to turn the dynamic optimization problem of intermediate good firms into a contraction mapping so that a value function iteration procedure can be used to find a solution in the numerical analysis.

In the model, an intermediate good industry at a certain technology gap n can transition out of that state with probabilities that depend on the innovation flow rates of each firm,

$$P_{n,n+1} = \frac{z_H^n}{z_H^n + z_F^n}; \qquad P_{n,n-1} = \frac{z_F^n}{z_H^n + z_F^n};$$

where $P_{n,n+1}$ and $P_{n,n-1}$ are the probabilities of moving from state n to states $n+1$ and $n-1$, respectively. The uniformization procedure adds a fictitious transition from a state into itself. Since either firm can make a successful innovation, the transition rate out of state n is given by $\lambda_n = z_H^n + z_F^n$. From the innovation function (15), firms flow rates of innovation are bounded above by $\bar{z} < \infty$. Thus, the transition rate λ_n is bounded above by $\lambda \equiv 2\bar{z} < \infty$. The procedure defines new transition probabilities (including the fictitious one),

$$\tilde{P}_{n,n+1} = \frac{\lambda_n}{\lambda} P_{n,n+1} = \frac{z_H^n}{2\bar{z}}$$

$$\tilde{P}_{n,n-1} = \frac{\lambda_n}{\lambda} P_{n,n-1} = \frac{z_F^n}{2\bar{z}}$$

$$\tilde{P}_{n,n} = 1 - \frac{\lambda_n}{\lambda} = 1 - \frac{z_H^n + z_F^n}{2\bar{z}};$$

and an effective discount factor,

$$\frac{\lambda}{\rho + \lambda} = \frac{2\bar{z}}{\rho + 2\bar{z}} < 1;$$

that, together with an adjustment of the stationarized profits (net of R&D costs),

$$\hat{}_H = \frac{{}^{n}_{HH} + {}^{n}_{HF}(1/\omega) \quad (z^n_H)}{+2z}$$

$$\hat{}_F = \frac{{}^{n}_{FF} + {}^{n}_{FH}\,\omega \quad (z^n_F)}{+2z};$$

allows to write the dynamic optimization problems in (40)-(41) as a contraction mapping:

$$v_i^n = \max_{z_i^n} \left\{ \hat{}_i + \sum_{n'=n-1}^{n+1} \bar{P}_{n;n'} v_i^{n'} \right\} \qquad \forall n \in \mathbb{Z}$$

Once this adjustment is made, the numerical procedure to obtain the results of Sections 3 and 4 consists of the following steps:

1. Choose values for the parameters of the model. In particular set values for the trade and FDI costs in each country.

2. Guess a value of $\omega \quad Y_H/Y_F$. A good initial guess is $A_H L_H / A_F L_F$. That takes into account potential asymmetries between the two countries and speeds up the process.

3. Calculate profits based on the values of trade and FDI costs, which define the conpetition regimes (see Tables 1-4).

4. Adjust the calculated profits as described in the uniformization procedure above.

5. Apply a value function iteration procedure to the contraction mapping defined above. Within each iteration of the value function, apply a best-response procedure to find the optimal innovation rates of each firm given what their rival chooses.

6. Once the innovation rates are obtained, calculate the industry proportions at different technology gaps using equations (18) and (44).

7. Use the proportions to calculate the competition indices and a new value of ω. If the new value differs from the guess in more than the set tolerance, update the guess with the calculated value and go back to step 2 until convergence is achieved.

8. After convergence of the ω fixed-point procedure, calculate the rate of economic growth given in (35), and store the results for the given values of the trade and FDI costs.

9. Repeat the entire procedure for new values of trade and FDI costs.