Uneven Firm Growth in a Globalized World*

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Abstract

The rapid growth of non-OECD firms' innovation, facilitated by knowledge diffusion from OECD, raises concerns about OECD firms' technological leadership and growth potential. To study the growth effects of OECD knowledge diffusion, I develop an open-economy endogenous growth model with strategic competition in domestic and global markets, supported by new empirical evidence. I find that increased OECD-to-non-OECD knowledge diffusion triggers divergent innovation responses among firms, intensifying foreign competition while weakening domestic competition for OECD countries. Consequently, long-run productivity growth may slow despite short-run gains. If OECD's initial technological distance among domestic firms were smaller, its initial global technological advantage were higher, or the increase in knowledge diffusion were smaller, both OECD and non-OECD would have experienced higher long-run growth. This knowledge diffusion is connected with broad macroeconomic trends across countries, including declining global output share of OECD, rising industrial concentration, slower productivity growth, and higher R&D-to-GDP ratios.

Keywords: endogenous growth, innovation, knowledge diffusion, globalization, heterogeneous firms.

JEL classification: E20, F60, O30, O40, O50.

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1 Introduction

Since the 1990s, OECD firms have experienced a dramatic decline in the share of global output, driven by the rapid growth of non-OECD nations like China and India.[1] Equally significant is the accelerating pace of innovation among leading firms in non-OECD economies. It is widely recognized that the rapid growth of these firms is fueled by the diffusion of knowledge from OECD. This includes the transfer of technology, expertise, and practices, which are facilitated through trade, FDI, and migration.[2]Notably, DeepSeek's AI chatbot—a system built on OpenAI's foundational technology yet positioned to compete with offerings from OpenAI and Google—has been labeled a "Sputnik Moment." Not only OpenAI and Google but also many other firms are increasingly tracking both the technological gap and innovation strategies of domestic and foreign rivals.[3]

To sustain growth potential, should OECD countries be concerned about the rapid growth of non-OECD firms? Is there an optimal technological gap between countries? How is this optimal gap affected by competition among domestic firms? To address these questions, we need to examine: How has the knowledge diffusion from OECD driven the rapid growth of non-OECD firms? How does this rapid growth impact the productivity growth of OECD countries, especially considering that firms' innovation decisions are influenced by their technological gaps relative to both domestic and foreign competitors?

In this paper, I make two key contributions. The first contribution is methodological. I develop an open-economy endogenous growth model, where firms make innovation decisions based on their technological gap from domestic and foreign competitors, as well as the decisions of their competitors - a concept referred to as "strategic innovation." This framework not only enables the endogenous determination of technological gaps across firms and competition in both domestic and foreign markets but also demonstrates that the impact of international knowledge diffusion on growth is non-linear. This non-linear effect depends on the initial technological distance among firms both within and across countries, as well as the magnitude of the increase in knowledge diffusion. Therefore, it is sufficiently rich for quantitative analysis. The second contribution is to document new empirical evidence that disciplines and validates the model, and to quantitatively assess the aggregate impacts of fast-growing non-OECD firms, an essential step given the complexity of various forces at play.

I find that the rapid growth of non-OECD firms, driven by increased knowledge spillovers from the OECD, leads to enhanced foreign competition that negatively impacts OECD innovation, and a larger foreign market size for OECD firms. This larger market size arises as the final demand

[1]A striking illustration of this shift is China's increase in global industrial production, which has surged from less than 5% in 1995 to nearly 32% today.

[2]For instance, China's Huawei and ZTE (telecommunications) grew into global leaders by leveraging partnerships with OECD firms such as Intel, Qualcomm, and Ericsson. India's Biocon (biopharma) expanded its R&D capabilities through collaborations with OECD companies like Pfizer. Brazil's Embraer (aerospace) benefited from technology transfers and licensing agreements with OECD manufacturers such as Boeing. Turkey's Baykar (drones) draw on technologies from European defense contractors. Indonesia's GoTo (consumer tech) benefit from investments and expertise from Japan's SoftBank. Additionally, many developing countries use *quid pro quo* policies requiring OECD firms to transfer technology in return for market access.

[3]When OpenAI released GPT-4, Google responded by accelerating the development of its own model, Gemini, to compete with GPT-4. OpenAI revealed more details about the reasoning process of o3-mini, as it faced mounting pressure from DeepSeek-R1, a competing model that fully discloses its reasoning tokens.

in non-OECD grows via general equilibrium effects. Such expansion favors the growth of leading OECD firms, ultimately weakening domestic competition and hampering the innovation of smaller OECD firms. Contrary to conventional wisdom that a larger foreign market increases innovation (Shu and Steinwender (2019)), I find a negative market size effect on innovation by showing how domestic competition is weakened. Additionally, I find harsher foreign competition does not motivate firms to innovate more, as weaker domestic competition diminishes their incentive to escape foreign competition. Compared to existing literature on international knowledge diffusion and endogenous growth (see, e.g., Sampson (2015, 2023), Prato (2024)), I model the evolving competition environment in both domestic and foreign markets and their interaction, and show that the long-run growth gains could be not as sizeable as previously thought.

In my model, firms optimize production for a domestic and a foreign market while investing in innovation driven by profits and knowledge spillovers within and across countries. My model extends the dynamic competition literature (e.g., Aghion et al. (2005, 2001, 1997), Akcigit and Ates (2023), Akcigit et al. (2018), Cavenaile et al. (2019, 2022), Olmstead-Rumsey (2022)) by having *dual focus*—modeling strategic innovation relative to both domestic and foreign competitors.[4] Models of this class are difficult to compute and analyze (cf. Liu et al. (2022)), and the addition of multi-dimensional strategic interactions further intensifies these complexities. I provide analytical results and develop a tractable numerical algorithm, demonstrating that my *dual focus* is critical for understanding the link between globalization and productivity growth.

My *dual focus* reveals two inverted-U shapes: as firms gain technological advantage over domestic or foreign competitors, their motivation to innovate initially increases and then decreases. Firms innovate to "escape competition" when they are close to rivals but are disincentivized by large gaps. The international inverted-U curve peaks later than the domestic one. A larger global technological advantage allows firms to secure more market share abroad, offsetting disincentives. Additionally, the presence of domestic competition flattens the international curve, as firms focus less on foreign competitors when they have to consider domestic competitors. In essence, both the incentive to escape foreign competition and the disincentives due to foreign competition are tempered by domestic competition.

Using patent data combined with nationally representative firm-level data from various OECD countries, I have primarily observed the decreasing part of the domestic inverted-U curve and the increasing part of the international inverted-U curve since the 1990s. Over time, the distribution of OECD firms has shifted towards the right tail of the domestic inverted-U curve and the left tail of the international inverted-U curve. These findings suggest that OECD firms' innovation decreases as technological distance among domestic competitors increases, or as technological distance relative to foreign competitors decreases. Furthermore, OECD firms have had an increased technological

[4] Akcigit et al. (2018) and Cavenaile et al. (2022) only considers strategic innovation relative to foreign competitors. Their focus is not international knowledge diffusion. I provide new empirical facts and new theoretical results to show its importance in affecting worldwide productivity growth as well as other macro phenomena. I also demonstrate that, if we overlook the impact of weakened domestic competition, the growth gains from accessing foreign markets are overestimated and the losses from exposure to intense foreign competition are underestimated. The gains are not as sizeable as previously thought, as foreign market access often favors larger firms and weakens domestic competition, reducing overall innovation. The losses are larger than anticipated, as the escape foreign competition incentive is diminished by domestic rivalry. Other work in this literature only considers strategic innovation relative to domestic competitors.

distance among domestic competitors, but a decreased technological distance relative to foreign competitors. I use these new facts to estimate firms' innovation incentives in the model, and show that increased knowledge diffusion from OECD explains these changes over time.

When estimating the model, I consider *an* OECD country (denoted by OECD or Home) trades with the rest of the world (denoted by ROW or Foreign).[5] As ROW is less productive than OECD, they get more knowledge spillovers from OECD. Similar to Sampson (2023), these spillovers can originate from trade or any other sources, including FDI or migration. These spillovers are disciplined by OECD's TFP relative to ROW, as increased spillovers reduce the TFP premium of OECD. When estimating spillovers, I rule out alternative factors that could reduce OECD's TFP premium (e.g., an increase in allocative efficiency due to reforms in ROW). This approach is consistent with existing literature, though the estimation is indirect. To address any concerns, I provide a range of estimates, alternative models of spillovers, and supporting facts.

I find that the increased international knowledge spillovers, which contribute to the rapid growth of ROW, diminish OECD firms' global technological advantage and global output share, resulting in profit losses. This intensifies foreign competition and reduces OECD innovation due to lower payoffs.[6] Meanwhile, the increased global output share of ROW enhances their final demand, which leads to a larger increase in export profits for OECD leaders and, therefore, greater returns to innovation compared to domestic followers. This additional innovation from the leaders enhances their technological advantages relative to domestic competitors, leading to higher domestic concentration.[7] Domestic concentration in ROW also rises as the growth of leading firms in ROW differentially benefit from knowledge spillovers.The R&D-to-GDP ratios increase as leading firms that incur higher innovation costs account for a larger market share. The model predictions are also supported by the industry-level data. Using summary statistics and regressions with instrumental variables, I find that industries facing larger foreign markets first experience increases in innovation and growth, followed by a slowdown in both. On average, these industries grew faster and became more concentrated than industries facing stiffer foreign competition. I also examine an alternative force of fast growing ROW - decreasing iceberg trade costs. I find it increases foreign demand but decreases domestic demand for OECD firms due to consumers' love-of-variety. Overall, this effect is dominated by the force of increasing international knowledge spillovers.[8]

The counterfactual analyses indicate that the growth effect of knowledge diffusion from OECD to ROW depends on three factors: the initial technological distance among domestic firms, OECD's initial global technological advantage, and the magnitude of the knowledge spillover increase, which

[5]ROW, rather than non-OECD is considered as OECD countries trade with each other.

[6]As interpreted through Aghion et al. (2001), the Schumpeterian effect of intensified foreign competition surpasses the innovation motive to escape foreign competition.

[7]In this paper, the terms "domestic concentration" and "industrial concentration" are used interchangeably. Industrial concentration captures the extent to which the share of sales or output accounted for by the largest firms among domestic firms within an industry.

[8]Decreasing iceberg trade costs is a well accepted force. Increasing international knowledge spillovers is considered in the spirit of real-world examples listed above, as well as studies by Rivera-Batiz and Romer (1991), Eaton and Kortum (1999), Keller (2002), Coe and Helpman (1995), and Coe et al. (2009), among others. These studies have documented a rise in international spillovers, contributing to cross-country TFP convergence in recent decades. Increased international knowledge spillovers could be a result of increased trade facilitated by decreasing trade costs, as detailed in Appendix B.

governs firms' incentives to compete with rivals. If OECD's initial technological distance among domestic firms were smaller (such that the negative growth effect of weaker domestic competition were lessened), the initial global technological advantage were higher (such that firms' innovation incentives to escape foreign competition were strengthened), or the increase in knowledge diffusion from OECD were smaller (such that the effects of weaker domestic competition and harsher foreign competition were not as strong), all countries would have had higher long-run growth. These results are supported by my new facts that industries with a high initial global technological advantage or a small initial technological distance among domestic firms exhibit higher innovation and growth.

These results suggest that for OECD, policymakers must consider the time-varying competition environment in both domestic and foreign markets. Policy interventions might only be necessary when the escape-competition motive diminishes. For non-OECD, policies aimed at minimizing the technological gap with the global technology frontier could be detrimental if they hinder the growth of this frontier, which ultimately determines the long-run growth of lagging nations—a new mechanism complementary to Prato (2024).[9] It is worth noting that these results do not advocate for deglobalizing policies. Instead, they highlight market inefficiencies that could reduce the growth gains of trading with a rapidly growing ROW—or, more broadly, of globalization. Counterfactual policies suggest that for OECD, protectionist policies could backfire by mitigating foreign competition at the expense of further weakening domestic competition. Policies that promote domestic competition and the growth of small firms generally lead to growth gains, even in the presence of harsher foreign competition.

Contribution to the literature. I contribute new facts on dual inverted-U shapes to the Schumpeterian growth and firm innovation literature (e.g., Aghion et al. (2005), Cavenaile et al. (2019)). My facts suggest that since the 1990s we have mainly observed the decreasing part of the "inverted-U" in the domestic market and the increasing part of the "inverted-U" in the international market. These observations not only update previous domestic market findings based on data from the 1970s, but also offer a unique international perspective.

Second, my *dual focus* contributes new mechanisms to the innovation, knowledge spillover, trade, and heterogeneous firm literatures as previously discussed (e.g., Sampson (2015, 2023), Akcigit et al. (2018), Cavenaile et al. (2022)).[10] My model not only confirms the harsher foreign competition effect but also reveals the less-emphasized market size effect of international knowledge spillovers.[11] My model underscores how large international firms impact other firms' innovation incentives, complementary to Edmond et al. (2015). My model helps explain some seemingly contradictory findings in existing empirical research (Autor et al. (2020a), Bloom et al. (2015)).[12]

[9]Prato (2024) finds that eliminating the brain drain in the EU by encouraging inventors to move back from the U.S. lowers growth in both the U.S. and the EU in the long run.

[10]Related models include Choi and Shim (2023), Akcigit et al. (2024), Atkeson and Burstein (2010), Bustos (2011), Aghion et al. (2018), Lim et al. (2018), Impullitti and Licandro (2018), Buera and Oberfield (2020), Perla et al. (2021), Cai et al. (2022), Hsieh et al. (2022), and others.

[11]This connects to earlier literature on the trade-off between the benefits of greater FDI and the costs of diminishing the value of intellectual property holdings (e.g., Grossman and Helpman (1993), Barro and Sala-I-Martin (1997), Holmes et al. (2015)).

[12]Autor et al. (2020a) find harsher foreign competition reduces innovation in the U.S., but Bloom et al. (2015) find harsher foreign competition increases innovation in Europe. My model helps explain these differing findings: as the U.S. has a higher domestic concentration level than Europe (Bajgar et al. (2023)),

Third, I provide new insights into the literature on misallocation, innovation, and firm dynamics (e.g., Restuccia and Rogerson (2008), Hsieh and Klenow (2009, 2014), Sui (2022, 2024)). I argue that globalization-driven resource allocation to more productive firms may lead to long-run growth losses, presenting a dynamic perspective on "misallocation." Innovation incentives may diminish due to changes in domestic or foreign competition. Moreover, highly productive large firms exhibit smaller innovation step sizes, in line with traditional models that predict faster growth for small firms. The increased market share of large firms can ultimately suppress aggregate growth.

Fourth, I contribute to the literature on rising domestic concentration and decelerating productivity growth by offering a unique open-economy perspective. For the first time, I link OECD trends with non-OECD trends, include international trends (e.g., increasing knowledge diffusion from OECD but declining global output share of OECD), and provide a unified explanation for why domestic followers became less innovative (Olmstead-Rumsey (2022)), and why more concentrated industries have faster productivity growth (Autor et al. (2020b)).[13]

2 Motivating Trends

In this section, I document three new facts. First, patents held by OECD firms are increasingly cited by non-OECD countries. This serves as suggestive, albeit imperfect, evidence of increasing knowledge spillovers from the OECD to developing nations. Second, the increased knowledge spillovers from OECD coincide with a surge in aggregate TFP growth, followed by a slowdown. Third, the initial technological distance with and across countries matters for growth. Industries with a high initial global technological advantage or a small initial technological distance among domestic firms exhibit relatively higher innovation and growth, despite all experiencing similar changes in knowledge spillovers. I also discuss their implications for my model construction.

2.1 Data, Variable Construction, and Sample Selection

I examine patents from the perspective of firms, not individual inventors. I employ the ORBIS Intellectual Property dataset, which compiles patents from various patent offices and directly links them to ORBIS Historical via firm ID. This dataset offers two advantages. First, it enables comparability across countries. Second, it captures innovation by both public and private firms, addressing the oversight of private firm innovation in previous studies due to limited data availability. I assign granted patents to their applicant firm and determine the patent year using its application year to capture the actual effective time of innovation, aligning with the literature.

Knowledge Diffusion. Granted patents are required to identify all citations made to previous patents upon which the current one is built. Consequently, patent citations act as a reasonable indicator of knowledge diffusion and are widely used in the literature. Moreover, they are a relatively clean measure of knowledge diffusion, especially considering that knowledge can be disseminated through immeasurable formats (e.g., consulting foreign experts). To this end, I

the weaker domestic competition in the U.S. reduces U.S. firms' incentive to escape foreign competition, thereby having a more negative effect on innovation than in Europe. Additionally, since the U.S. has lower trade openness than Europe, my model predicts that the U.S. would place more emphasis on domestic competitors, thereby showing a reduced motive to escape foreign competition.

[13]The rising domestic concentration and slower productivity growth in OECD countries are usually examined within one-country frameworks (e.g., Akcigit and Ates (2021, 2023), Liu et al. (2022), Olmstead-Rumsey (2022), Peters and Walsh (2022), Aghion et al. (2023), De Ridder (2024), Bloom et al. (2020), Cavenaile et al. (2022), Hopenhayn et al. (2022), Ekerdt and Wu (2022), Firooz et al. (2022), Kalyani (2022)).

calculate annually for each firm the percentage of self-citations and citations from non-OECD foreign firms it receives, based on newly granted patents.

Innovation Quality, Innovation Quantity, and TFP Growth. Citations act as both an indicator of knowledge diffusion and a measure of innovation quality. Higher citations for a patent typically signify superior innovation quality and are associated with faster productivity growth (see, e.g., Acemoglu et al. (2022)). Consequently, I use the average number of citations per newly granted patent for each firm each year to approximate firm patent quality. Citations are adjusted following the truncation correction weights developed by Hall et al. (2001) to address systematic differences in patent citing across industries and how earlier patents have more years during which they can receive citations. Innovation quantity is measured by the number of newly granted patents for each firm each year. To alleviate concerns that some productivity growth is not captured by patenting activities, I compute the TFP growth rate using the 2019 release of EU KLEMS. To address cyclicality issues in calculating one-year growth rates, I compute annualized five-year TFP growth.

Domestic Technology Gap in an OECD Country. Ideally, the technology distance could be measured using the true productivity of firms. However, without firm-level price information, it is difficult to measure firm productivity. I instead utilize sales, which are directly observable and correlated with a firm's productivity in the data. I define leaders as the top one percent of firms by sales within each industry and year in each country. Sales include both domestic sales and foreign sales (exports). All other firms are followers.[14] The leaders' sales share within an industry-country pair (i.e., domestic concentration) is used to measure domestic technology gaps, with a larger share indicating a higher domestic gap and a greater technological advantage of leaders over followers.

Global Technology Gap between an OECD Country and ROW. Similarly, global output shares at the country-industry-year level are used to determine the global technology gaps between a country and the rest of the world. The global output share is calculated using each country's ratio of output to total world imports in each industry each year, based on the 2021 release of the OECD Input-Output Tables (IOTs) and Inter-Country Input-Output tables. A larger global output share suggests a larger global gap and a greater technological advantage over the rest of the world.

Sample Selection and Robustness. For most data series, I use annual data from 1995 to 2015, based on data availability. For ORBIS Historical, the data starts from 1999, as from that year, all firms located in an EU country are required to file with the registries.

Country Coverage. I consider not only the U.S., with its significant global impact, but also twelve European OECD countries with good data coverage on balance sheet information.[15] Note that the patterns I document are qualitatively robust when the U.S. is excluded, indicating that both the U.S. and European countries exhibit similar trends.

Patent Office Coverage. I focus on patents filed with the U.S. patent office to avoid any possibility of double counting the same patents across multiple patent offices. This approach is informed by existing literature (e.g., Cai et al. (2022)), which suggests that most important innovations relevant

[14] This measure is in line with recent literature. Although some leaders in specific years may not remain leaders in future years, leaders are increasingly likely to remain so over time, consistent with evidence in Olmstead-Rumsey (2022).

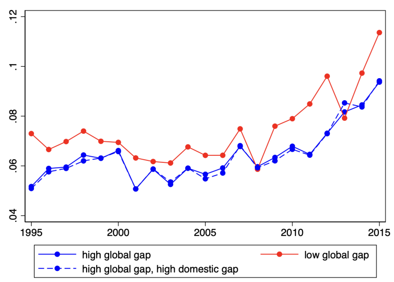
[15] The twelve European countries are France, Germany, the UK, Greece, Spain, Italy, Portugal, Finland, Sweden, the Netherlands, Denmark, and Norway. European countries cover both private and public firms, while the U.S. only covers public ones.

for productivity growth from other countries have been patented in the U.S., thus minimizing concerns about sample selection issues. However, the patterns I document remain robust when using patents from the European patent office.

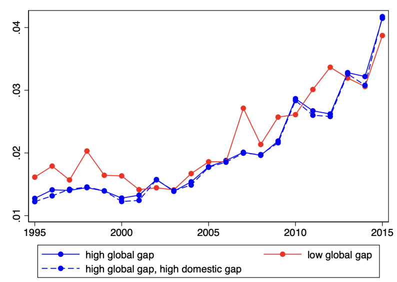
Industry Coverage. I use two-digit NACE Rev.2 industry classification for ORBIS and merge it with ISIC Rev.4 used in OECD IOTs and EU KLEMS. Since the focus of the paper is primarily tradable sectors, I select the manufacturing sector and the information and communication sector, which are tradable and account for more than 80 percent of total patenting. Robustness checks extended to all non-government non-financial industries find consistent results.

2.2 Motivating Facts

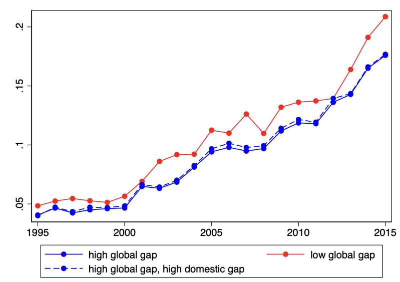
Figure 2.1: Motivating Trends



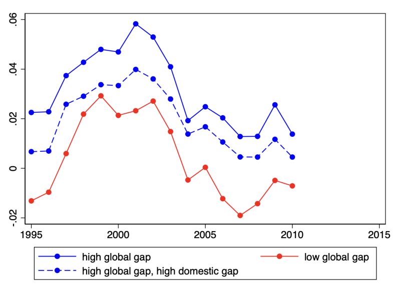
(a) non-OECD forward share



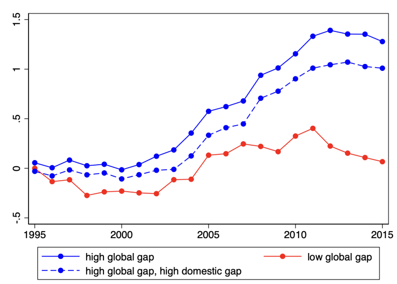
(b) non-OECD backward share



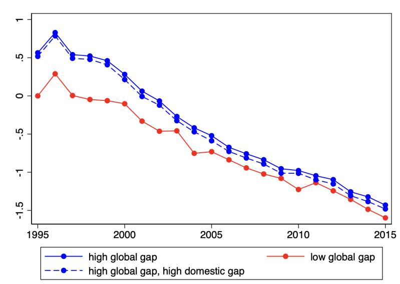
(c) self-citation share



(d) annualized TFP growth



(e) log(number of patents)



(f) log(citations per patent)

Notes: This figure categorizes industries into high and low initial global technology gaps based on the median level of global output share prior to 2005 for each country. Among industries with a high global technology gap in a country, they are further classified into high and low initial domestic technology gaps based on the 75th percentile of domestic concentration before 2005. It highlights patterns in the manufacturing and ICT service sectors, which are tradable and account for approximately 80 percent of patenting activities in the total economy. The plot includes data from the U.S. and twelve European countries, weighted by country-industry-specific output. The non-OECD forward citation share is the fraction of citations a firm receives from non-OECD foreign firms among all non-self citations. The non-OECD backward citation share is the fraction of citations a firm cites from non-OECD foreign firms among all non-self citations. The self-citation share is the fraction of citations a firm receives from itself. TFP growth in year t is represented by the annualized 5-year TFP growth from year t to $t + 5$. Figure E.1 instead illustrates the fraction of citations a firm receives from non-OECD foreign firms among all citations.

Fact 1. Patents held by OECD firms are increasingly being cited by non-OECD countries. OECD firms are also increasingly citing non-OECD patents, but the magnitude of this increase is much smaller than the former. Fact 1 is demonstrated by Panels (a) and (b) in Figure 2.1.[16] Two points are worth mentioning. First, these international knowledge spillovers may or may not be incorporated into trade flows. Various spillovers, such as learning through exporting and FDI, may

[16]Figure E.1 reveals this trend persists regardless of whether I consider the fraction of non-OECD citations among all citations or among non-self citations; this trend remains consistent even when China is excluded from the non-OECD group. Conversely, the fraction of citations from other OECD countries does not increase and appears to decline.

not be fully captured by citations, so citations could represent a lower bound of knowledge transfer from OECD to non-OECD firms. Second, the increase in international knowledge spillovers likely began earlier than indicated by citation records. Specifically, Figure 2.1 shows a rise in non-OECD citations from the 2000s, but the actual spillovers could have started in the 1990s or even earlier, as suggested by early literature (e.g., Keller (2002)). Countries in early stages of development typically learn from the global technological frontier by adopting existing technology instead of innovating or filing patents, a well-documented fact.

Fact 2. The increase in knowledge spillovers from OECD to non-OECD countries coincides with a surge in TFP growth, followed by a growth slowdown. The TFP growth slowdown coexists with an innovation slowdown. Fact 2 is shown by Panels (d), (e) and (f) in Figure 2.1. Since around 2005, TFP growth has slowed down. Before 2005, the quality of innovation had been declining, but the increase in the quantity of innovation outweighed the negative effect of the declining quality, contributing to a surge in TFP growth.[17]

Fact 3. The initial technological distance within and across countries plays a significant role in innovation and growth. Industries that start with a high global technological advantage or a small initial technological distance among domestic firms exhibit relatively higher levels of innovation and growth. This occurs despite all experiencing similar changes in knowledge spillovers. The role of the initial global technological advantage is highlighted by the differences between the blue and red lines in Figure 2.1. I find that industries with a low initial global technological advantage are typically low-tech industries. Given that non-OECD countries possess a comparative advantage in these industries and are therefore more capable of learning from and citing OECD countries, it is not surprising to see that these industries in OECD countries have slightly more citations from non-OECD countries. Likewise, these industries in OECD countries more frequently cite patents filed by non-OECD countries.

The role of the initial technological distance among domestic firms is emphasized by the differences between the blue solid lines and the blue dashed lines. While industries with different technological distance among domestic firms experience a similar increase in non-OECD citations over time, they exhibit different changes in patenting and TFP growth.

Model Mechanism Motivation. Fact 3 indicates that industries experiencing similar changes in knowledge spillovers could have different changes in patenting and TFP growth, depending on the initial technological distance within and across countries. This calls for a model that characterizes the role of technological distance both within and across countries, and allows for firms with different technological distances to respond differently to the same change in international knowledge spillovers. In fact, considering the industry-level variation in international knowledge spillovers strengthens my model predictions.[18]

It is worth mentioning that Panel (c) in Figure 2.1 indicates an increase in the fraction of self-citations among OECD firms. The increasing self-citation can be interpreted in two ways. First, it

[17] I exclude patents filed by individual inventors when computing the total number of patents for each OECD country. When including patents filed by individual inventors and considering all countries filing patents in the U.S. patent office, I observe a more significant increase in the number of patents over time.

[18] A larger increase in international knowledge spillovers in industries with low global technological advantage leads to fiercer foreign competition, which hurts firms' innovation incentives and growth, as detailed in section 3.

can be seen as more incremental innovations (as documented by Akcigit and Kerr (2018), where incremental innovations typically aim to improve firms' existing products, and new patents will cite many patents from the firm's existing portfolio), which contributes to an innovation slowdown and TFP growth slowdown. Second, it can be seen as reflecting more defensive innovation motives (as studied by Akcigit and Ates (2023), where self-citations often serve to protect firms' existing core technology), which contributes to less domestic knowledge diffusion. As detailed in section 4.5.3 and Appendix B.3, both interpretations can be induced by the increase in international knowledge spillovers and hence, strengthen my model predictions.[19] However, to avoid ruling out alternative drivers of the increase in self-citations, in the baseline analysis, I consider the change in non-OECD citations and self-citations independently.[20]

3 The Model

The economy is in continuous time and consists of two countries, Home and Foreign, indexed by $c \in \{H, F\}$. I focus on the Markov Perfect Equilibrium where the strategies (firm decisions) are only functions of the payoff-relevant state.

Household In each country there is a representative household who maximizes its utility

$$U_{ct} = \int_t^\infty \exp(-\rho(s-t)) \ln(C_{cs}) ds, \tag{3.1}$$

subject to the flow budget constraint $P_{ct}C_{ct} + \dot{A}_{ct} = w_{ct}L_c + r_{ct}A_{ct}$, where $\rho > 0$ is the discount factor, C_{ct} represents consumption of the final good at time t in country c, P_{ct} denotes the price of the final good, L_c is the fixed amount of labor, w_{ct} is the wage, $A_{ct} = \int_{\mathcal{F}} V_{fct} df$ is the sum of firm values with $\mathcal{F}$ denoting the set of firms, and r_{ct} is the rate of return on the portfolio of firms.[21] The household owns all domestic firms and inelastically supplies a fixed measure of labor that is immobile between countries. Home wage is the numeraire. The utility maximization problem generates an Euler equation:

$$r_{ct} = \frac{\dot{C}_{ct}}{C_{ct}} + \frac{\dot{P}_{ct}}{P_{ct}} + \rho, \tag{3.2}$$

where $\frac{\dot{C}_{ct}}{C_{ct}}$ ($\frac{\dot{P}_{ct}}{P_{ct}}$) is the growth rate of aggregate consumption (price level).

Final Good Technology Perfectly competitive firms in each country produce a non-tradable final good Y_{ct} with the technology $Y_{ct} = \exp[\int_0^1 \ln(Y_{jct}) dj]$. Y_{jct} is the output from a continuum of industries $j \in [0, 1]$ in country c:

$$Y_{jHt} = [\sum_{i=1}^{2} \omega_{ijHt}(z_{ijHt}y_{ijHt})^{\frac{\epsilon-1}{\epsilon}} + \sum_{i=1}^{2} \omega_{ijFt}(z_{ijFt}y_{ijFt})^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}, \tag{3.3}$$

[19] As knowledge is embodied in plants, a widely accepted fact, the rise of offshore production in the era of globalization could also lead to a reduction in domestic knowledge diffusion.

[20] Figure 2.1 shows that industries with low initial global technological advantage in OECD countries exhibit slightly higher self-citations on average. As detailed later, my model shows these industries experience more intense foreign competition and a more significant innovation slowdown, which can be micro-founded by both perspectives—either more incremental innovation or declining domestic knowledge diffusion.

[21] Trading in assets across countries is not allowed so there is no international borrowing and lending.

$$Y_{jFt} = [\sum_{i=1}^{2} \omega_{ijFt}(z^*_{ijFt}y^*_{ijFt})^{\frac{\epsilon-1}{\epsilon}} + \sum_{i=1}^{2} \omega_{ijHt}(z^*_{ijHt}y^*_{ijHt})^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}, \tag{3.4}$$

where ω_{ijct} denotes the mass of the firm $i \in \{1,2\}$,[22] $z_{ijct} = \omega^{b}_{ijct}{}^{\frac{1}{\epsilon-1}} q_{ijct}$, $z^*_{ijct} = \omega^{*b}_{ijct}{}^{\frac{1}{\epsilon-1}} q_{ijct}$, ω^b_{ijct} and ω^{*b}_{ijct} represent the demand shifters for Home and Foreign, respectively, q_{ijct} denotes firm productivity, and $\epsilon > 1$ is the elasticity of substitution across intermediate goods within an industry.[23] y_{ijHt} (y^*_{ijHt}) denotes the amount sold by a Home intermediate good firm to Home (Foreign) final good producers. I indicate other variables with an asterisk in a similar fashion and introduce only Home problems. Foreign problems are symmetric. Home final good producers buy intermediate goods at prices p_{ijHt} and p_{ijFt}, and sell the final good at price P_{Ht}. Home final good producers choose intermediate quantities y_{ijHt} and y_{ijFt} to maximize profits, which gives the demand functions

$$y_{ijHt} = z^{\epsilon-1}_{ijHt}(\frac{p_{ijHt}}{P_{jHt}})^{-\epsilon}\frac{P_{Ht}Y_{Ht}}{P_{jHt}} \quad \text{and} \quad y_{ijFt} = z^{\epsilon-1}_{ijFt}(\frac{\tau_F p_{ijFt}}{P_{jHt}})^{-\epsilon}\frac{P_{Ht}Y_{Ht}}{P_{jHt}}, \tag{3.5}$$

where the aggregate price index is $P_{Ht} = \exp[\int_0^1 \ln(P_{jHt})dj]$ and the industry price index is $P_{jHt} = (\sum_{i=1}^2 \omega_{ijHt} z^{\epsilon-1}_{ijHt} p^{1-\epsilon}_{ijHt} + \sum_{i=1}^2 \omega_{ijFt} z^{\epsilon-1}_{ijFt}(\tau_F p_{ijFt})^{1-\epsilon})^{\frac{1}{1-\epsilon}}$.

Intermediate Good Production and Innovation Intermediate good firms produce according to a linear production technology $y^T_{ijct} = q_{ijct} l_{ijct}$, where l_{ijct} is the labor used for producing output y^T_{ijct}, and q_{ijct} is firm productivity. Intermediate good firms sell output to final good producers in both countries. Selling to the foreign market (exporting) is subject to iceberg trade costs $\tau_c \geq 1$. The resource constraint for Home intermediate good firms is $y^T_{ijHt} = y_{ijHt} + \tau_H y^*_{ijHt}$, so $\tau_H y^*_{ijHt}$ must be shipped for y^*_{ijHt} to be sold to Foreign.

Price setting. The constant returns production technology enables analysis of firms' decisions in the Home and Foreign markets separately. The profit maximization problem in the domestic market leads to to a markup price-setting rule:

$$p_{ijHt} = \frac{\varepsilon_{ijHt}}{\varepsilon_{ijHt}-1}\frac{w_{Ht}}{q_{ijHt}}, \quad \varepsilon_{ijHt} \equiv \epsilon - (\epsilon-1)s_{ijHt}, \tag{3.6}$$

where ε_{ijHt} is the domestic demand elasticity faced by the Home firm and $s_{ijHt} \in [0,1]$ is its domestic market share: $s_{ijHt} \equiv \frac{\omega_{ijHt}p_{ijHt}y_{ijHt}}{\sum_{i=1}^2 \omega_{ijHt}p_{ijHt}y_{ijHt} + \tau_F \sum_{i=1}^2 \omega_{ijFt}p_{ijFt}y_{ijFt}} = \omega_{ijHt} z^{\epsilon-1}_{ijHt}(\frac{p_{ijHt}}{P_{jHt}})^{1-\epsilon}$. Similarly, the markup-pricing-setting rule in the foreign market is $p^*_{ijHt} = \frac{\varepsilon^*_{ijHt}}{\varepsilon^*_{ijHt}-1}\frac{w_{Ht}}{q_{ijHt}}$, where $\varepsilon^*_{ijHt} = \epsilon - (\epsilon-1)s^*_{ijHt}$, and $s^*_{ijHt} = \omega_{ijHt} z^{\epsilon-1}_{ijHt}(\frac{\tau_H p^*_{ijHt}}{P_{jFt}})^{1-\epsilon}$. The optimal profits of Home intermediate firms across both markets are then obtained as $\Pi_{ijHt}P_{Ht}Y_{Ht}$, where

$$\Pi_{ijHt} \equiv [(1 - \frac{\varepsilon_{ijHt}-1}{\varepsilon_{ijHt}})s_{ijHt}] + [(1 - \frac{\varepsilon^*_{ijHt}-1}{\varepsilon^*_{ijHt}})s^*_{ijHt}]\frac{P_{Ft}Y_{Ft}}{P_{Ht}Y_{Ht}}. \tag{3.7}$$

[22] Two firms per country per industry can be considered a special case of N firms from each country – ω_{1jct} fraction of firms are identical and are treated as firm 1, and ω_{2jct} fraction of firms are identical but different from firm 1, which are treated as firm 2.

[23] Including demand shifters in the final good technology is common in trade literature, while the inclusion of productivity in the final good technology is common in the growth literature, yielding higher demand for goods with higher productivity.

As proved in Appendix, firm market shares depend only on the relative prices within each industry. This implies that all firms' strategic considerations take place within an industry and are invariant to prices outside a given industry. Since firms' production and pricing decisions are essentially static, the subscript t can be omitted.

Technology leaders. The higher-productivity firm in each country-industry is called the *domestic leader*, paired with a *domestic follower* (*leader* and *follower* for simplicity). Domestic leaders with higher productivity than their international competition are *global leaders*. The leader (follower) is denoted by $i = 1$ ($i = 2$) so that $q_{1jct} \geq q_{2jct}$. Firms are in a *neck-and-neck* position when they have the same productivity and both firms act as leaders. Backward firms can replace domestic or global leaders by improving their productivity through innovation investment or getting knowledge spillovers.

Technology gaps. Firm i in industry j at time t has a technology level $q_{ijct} \equiv \lambda^{m_{ijct}}$, where $m_{1jct} \geq m_{2jct}$ and $m_{1jct}, m_{2jct} \in \mathbb{N}$ represent the technology rungs of firms. The relative productivity between the two domestic firms is then $\frac{q_{1jct}}{q_{2jct}} = \lambda^{m_{1jct}-m_{2jct}}$ and the relative productivity between each leader is $\frac{q_{1jHt}}{q_{1jFt}} = \lambda^{m_{1jHt}-m_{1jFt}}$. Define $m_{jct} \equiv m_{1jct} - m_{2jct}$ as the *domestic technology gap* in industry j and country c, $c \in \{H, F\}$. Define $m_{jGt} \equiv m_{1jHt} - m_{1jFt}$ as the *global technology gap* in industry j, where $m_{jGt} \geq 0$ if the Home firm is the global leader and $m_{jGt} < 0$ if the Foreign firm is the global leader. These technology gaps are the only industry-specific payoff-relevant state variables, so the subscript j can be omitted and technology gaps can be denoted by $\boldsymbol{m} \equiv \{m_H, m_F, m_G\}$. The domestic gap is $m_c \in \{0, 1, ..., \bar{m}_c\}$ and the global gap is $m_G \in \{-\bar{m}_G, ..., 0, ..., \bar{m}_G\}$.[24]

Innovation. Intermediate firms' innovations follow a controlled Poisson process, with the arrival rate $x_{ict}(\boldsymbol{m})$ determined by their innovation investment. Let $R_{ict}(\boldsymbol{m}) \equiv \frac{\alpha_{ic}}{\gamma_{ic}} x_{ict}^{\gamma_{ic}}(\boldsymbol{m}) Y_{ct}$ denote their innovation investment denominated in domestic final goods, where $\alpha_{ic} > 0$ represents the scale of innovation cost, $\gamma_{ic} > 1$ implies innovation investment is convex in the arrival rate, and Y_{ct} ensures that the cost scales with the size of the economy. A higher arrival rate is associated with increased innovation investment and an elevated innovation incentive.[25] A firm with $\boldsymbol{m} = \{m_c, m_{\tilde{c}}, m_G\}$ that successfully innovates will change the technology gaps to $\boldsymbol{m}' = \{m'_c, m_{\tilde{c}}, m'_G\}$ according to a probability function $F_{ic}(m_c, m_G, m'_c, m'_G)$, where $\tilde{c} \neq c$.[26] For comparison with previous papers, I consider a special case, i.e., a firm can either improve its productivity by one step or close the technology gap with the domestic or global leader.[27]

Leaders. Suppose Home leaders are global leaders with $m_G \geq 0$. They invest in innovation to improve their productivity by $\lambda > 1$. A successful innovation increases their domestic technology gap to $m'_H = m_H + 1$ and their global technology gap to $m'_G = m_G + 1$. When Home leaders are

[24]The non-negative domestic gap is introduced for computational simplicity, without disregarding the potential for followers to replace leaders. This transition is captured by the change in the firm index from $i = 2$ to $i = 1$. For computational feasibility the technology gap is finite.

[25]Within a time interval Δt, the probability of an innovation occurring is $x_{ict}(\boldsymbol{m})\Delta t + o(\Delta t)$, where $o(\Delta t)$ represents terms that satisfy $\lim_{\Delta t \to 0} o(\Delta t)/\Delta t = 0$. This also implies that the probability of more than one innovation arriving within the time interval Δt is $o(\Delta t)$.

[26]Note that a firm can only change its own domestic technology gap and the global technology gap given that the probability of more than one innovation arriving within the time interval Δt is $o(\Delta t)$.

[27]Some existing papers model that firms catch up with leaders slowly (e.g., Aghion et al. (2005), Liu et al. (2022)) while others model quick catch-up (e.g., Aghion et al. (2001), Akcigit et al. (2018), Akcigit and Ates (2023), Akcigit et al. (2024)).

not a global leader ($m_G < 0$), they have a probability of $1 - \delta_H$ to improve their productivity by λ and gradually catch up with their global leader. With a probability of δ_H, they directly reach the frontier productivity level, a global technology gap of $m'_G = 0$, regardless of their initial state.

Followers. Suppose Home firms are global leaders ($m_G \geq 0$). The successful innovation of a Home follower closes its domestic gap to $m'_H = 0$ with probability ϕ_H regardless of its initial state, or improves its productivity by λ such that $m'_H = m_H - 1$ with probability $1 - \phi_H$.[28] If Home firms are not global leaders ($m_G < 0$), the Home follower not only has probability ϕ_H of quick domestic catch-up, but also has probability δ_H to close the global gap to $m'_G = 0$ and overtake the Home leader such that $m'_H = |m_G|$, quick international catch-up. With probability $1 - \phi_H - \delta_H$, the Home follower only improves its productivity by λ. Of note, the quick catch-up probabilities of followers also capture that, conditional on successful innovation, smaller firms increase productivity faster and are more likely to engage in "radical" innovation, consistent with existing research (e.g., Akcigit and Kerr (2018)). $F_{ic}(m_c, m_G, m'_c, m'_G)$ for the Home firm is summarized as follows:

$$F_{1H}(m_H, m_G, m'_H, m'_G) = \begin{cases} 1 & \text{if } m'_H = \min\{m_H + 1, \bar{m}_H\}, m'_G = \min\{m_G + 1, \bar{m}_G\}, \text{and } m_G \geq 0, \\ 1 - \delta_H & \text{if } m'_H = \min\{m_H + 1, \bar{m}_H\}, m'_G = \min\{m_G + 1, \bar{m}_G\}, \text{and } m_G < 0, \\ \delta_H & \text{if } m'_H = \min\{m_H + |m_G|, \bar{m}_H\}, m'_G = 0, \text{and } m_G < 0, \\ 0 & \text{otherwise.} \end{cases}$$

$$F_{2H}(m_H, m_G, m'_H, m'_G) = \begin{cases} 1 - \phi_H & \text{if } m'_H = \max\{m_H - 1, 0\}, m'_G = m_G, m_H > 0, \text{and } m_G \geq 0, \\ \phi_H & \text{if } m'_H = 0, m'_G = m_G, \text{and } m_H > 0 \\ \delta_H & \text{if } m'_H = \min\{|m_G|, \bar{m}_H\}, m'_G = 0, m_H > 0 \text{ and } m_G < 0, \\ 1 - \phi_H - \delta_H & \text{if } m'_H = \max\{m_H - 1, 0\}, m'_G = m_G, m_H > 0 \text{ and } m_G < 0, \\ 0 & \text{otherwise.} \end{cases}$$

Knowledge spillovers. In each industry, within a time interval Δt, a firm receives exogenous *domestic knowledge spillovers* from its domestic competitor with probability κ or *international knowledge spillovers* from foreign competitors with probability ι if its productivity is lower than its competitors. Domestic and international spillovers capture the "benefits to backwardness," ensuring the existence of a non-degenerate steady state and that countries share a common growth rate along the balanced growth path (BGP). However, the level of productivity across countries may differ due to varying innovation intensities, consistent with Klenow and Rodriguez-Clare (2004). Neck-and-neck firms are unable to receive spillovers from each other. These spillovers are free and can be treated as extra chances to increase productivity beyond that expected from costly innovation investment. The resulting productivity improvement is identical to the specification above.

As many knowledge spillovers are free (e.g., interactions with international suppliers or buyers) and intellectual property rights are poorly enforced in many countries, along with data limitations, I do not model the rents of firms generating such spillovers. However, as detailed later, the international knowledge spillovers create a market size effect, which can be considered as the rents and incentivize innovation by firms generating these spillovers.

Value function and innovation decisions. Taking as given other firms' decisions, the value function of the Home leader is

$$r_{Ht} V_{1Ht}(\boldsymbol{m}) - \dot{V}_{1Ht}(\boldsymbol{m}) = \max_{x_{1Ht}(\boldsymbol{m}) \in [0, \bar{x}]} \{\Pi_{1Ht}(\boldsymbol{m}) P_{Ht} Y_{Ht} - P_{Ht} R_{1Ht}(\boldsymbol{m})$$

$$+ (x_{1Ht}(\boldsymbol{m}) + \iota \cdot \mathbb{1}_{m_G < 0}) [\sum_{m'_H} \sum_{m'_G} F_{1H}(m_H, m_G, m'_H, m'_G) V_{1Ht}(m'_H, m_F, m'_G) - V_{1Ht}(\boldsymbol{m})]$$

[28] Domestic neck-and-neck firms ($m_c = 0$) are both leaders, with $\phi_c = 0$ and $F_{1c}(m_c, m_G, m'_c, m'_G)$.

$$+ (x_{2Ht}(\boldsymbol{m}) + \kappa \cdot \mathbb{1}_{m_H<0} + \iota \cdot \mathbb{1}_{m_G<0})[\sum_{m'_H}\sum_{m'_G} F_{2H}(m_H, m_G, m'_H, m'_G)V_{1Ht}(m'_H, m_F, m'_G) - V_{1Ht}(\boldsymbol{m})]$$

$$+ (x_{1Ft}(\boldsymbol{m}) + \iota \cdot \mathbb{1}_{m_G>0})[\sum_{m'_F}\sum_{m'_G} F_{1F}(m_F, m_G, m'_F, m'_G)V_{1Ht}(m_H, m'_F, m'_G) - V_{1Ht}(\boldsymbol{m})]$$

$$+ (x_{2Ft}(\boldsymbol{m}) + \kappa \cdot \mathbb{1}_{m_F<0} + \iota \cdot \mathbb{1}_{m_G>0})[\sum_{m'_F}\sum_{m'_G} F_{2F}(m_F, m_G, m'_F, m'_G)V_{1Ht}(m_H, m'_F, m'_G) - V_{1Ht}(\boldsymbol{m})]\} \tag{3.8}$$

where $\dot{V}_{1Ht}(\boldsymbol{m})$ denotes the derivative of $V_{1Ht}(\boldsymbol{m})$ with respect to time and $\mathbb{1}_{m_k<0}$ denotes an indicator function that is equal to 1 if $m_k < 0$ and equal to 0 otherwise, $k \in \{H, F, G\}$. Other firm problems are analogously given with the corresponding firm subscript i and country subscript c.[29] A forward-looking firm invests in innovation with the hope of enhancing its relative technological position and reaping higher profits in the future. The flow value of the firm in state $\boldsymbol{m}$ is composed of flow profit net of innovation investment and the change of value due to its own and its competitors' productivity improvement outcomes. The first line on the right hand side of equation (3.8) captures the flow profit net of innovation investment. Other lines represent the change in value resulting from productivity increase of Home leaders, Home followers, Foreign leaders, and Foreign followers, either through their own successful innovation or by receiving knowledge spillovers from others.

Define the normalized value v_{ict} such that $v_{ict}(\boldsymbol{m}) \equiv \frac{V_{ict}(\boldsymbol{m})}{P_{ct}Y_{ct}}$, we derive the following optimal innovation decision for a Home leader:

$$x_{1Ht}(\boldsymbol{m}) = \left(\frac{\sum_{m'_H}\sum_{m'_G} F_{1H}(m_H, m_G, m'_H, m'_G)v_{1Ht}(m'_H, m_F, m'_G) - v_{1Ht}(\boldsymbol{m})}{\alpha_{1H}}\right)^{\frac{1}{\gamma_{1H}-1}}, \tag{3.9}$$

and symmetrically for other firms. The innovation decisions indicate that more value from innovation, driven by a larger innovation step size (i.e., higher productivity increase) or a higher profit increase, leads to a higher innovation rate. Knowledge spillovers and competitors' innovation decisions indirectly affect innovation incentives via their effects on the value of the firm.

Technology Gap Distribution and Aggregate Growth The share of industries with technology gaps $\boldsymbol{m}$ are denoted by $\mu_t(\boldsymbol{m})$ such that $\sum_{\boldsymbol{m}} \mu_t(\boldsymbol{m}) \equiv 1$, where $\boldsymbol{m} = \{m_H, m_F, m_G\}$. The technology gaps in each industry follow an endogenous Markov process with transition probabilities governed by firm innovation rates and knowledge spillovers, as detailed in Appendix A.1. Define the aggregate productivity index as $Q_{ct} \equiv \sum_{\boldsymbol{m}} \ln q_{1ct}(\boldsymbol{m})\mu_t(\boldsymbol{m})$, where $q_{1ct}(\boldsymbol{m})$ is the domestic leader's productivity in country c and state $\boldsymbol{m}$ at period t. Proposition 1 shows that two countries have identical growth rate along the balanced growth path. Proposition A.1 in Appendix proves that the growth of Q_{ct} defines the aggregate productivity growth rate and similarly for aggregate output, consumption, and prices.

Proposition 1. *Along the balanced growth path, the growth rate of aggregate Home productivity is* $g_H = \{\sum_{0\le m_H\le \bar{m}_H}\sum_{0\le m_F\le \bar{m}_F}\sum_{m_G\ge 0}[x_{1H}(\boldsymbol{m}) \cdot \mu(\boldsymbol{m}) + x_{2H}(\boldsymbol{m}) \cdot \mathbb{1}_{m_H=0} \cdot \mu(\boldsymbol{m})] + \sum_{0\le m_H\le \bar{m}_H}\sum_{0\le m_F\le \bar{m}_F}\sum_{m_G\le 0}[x_{1F}(\boldsymbol{m}) \cdot \mu(\boldsymbol{m}) + x_{2F}(\boldsymbol{m}) \cdot \mathbb{1}_{m_F=0} \cdot \mu(\boldsymbol{m})]\} \cdot \ln(\lambda)$, *where* $\boldsymbol{m} =$

[29]These subscripts are included in the firm value function because leaders and followers in each country can have different productivity given the same technology gaps.

$\{m_H, m_F, m_G\}$. *Home and Foreign have identical growth rate, i.e.,* $g_H = g_F$.

Markov Perfect Equilibrium A Markov Perfect Equilibrium of the two-country open economy consists of prices $\{r_{ct}, w_{ct}, P_{ct}, p_{ict}, p^*_{ict}\}^{c\in\{H,F\},t\in[0,\infty)}_{i\in\{1,2\},j\in[0,1]}$ and an allocation $\{y_{ict}, y^*_{ict}, l_{ict}, l^*_{ict}, x_{ict}, Y_{ct}, C_{ct}, L_c, R_{ct}, \{\mu_{\boldsymbol{m}t}, Q_{\boldsymbol{m}t}\}_{\boldsymbol{m}\equiv(m_c,m_{c'},m_G)}\}^{c,c'\in\{H,F\},t\in[0,\infty)}_{i\in\{1,2\},j\in[0,1]}$ such that for any $m_c \in \{0, ..., \bar{m}_c\}$, $m_G \in \{-\bar{m}_G, ..., 0, ..., \bar{m}_G\}$ and all t,
(i) households choose C_{ct} and A_{ct} to solve their utility maximization problem;
(ii) final goods firms solve their problem to optimally buy intermediate goods y_{ict} and y^*_{ict};
(iii) intermediate goods firms choose y_{ict}, y^*_{ict}, l_{ict}, l^*_{ict}, p_{ict}, p^*_{ict} to solve their production, employment, and pricing decisions, and x_{ict} to solve their innovation decision;
(iv) the asset market clears as in equation (3.2), pinning down r_{ct};
(v) the labor market clears, $L_c = \int_0^1 \sum_{i=1}^2 \omega_{ijct}(l_{ijct} + l^*_{ijct})dj$, pinning down w_{ct};
(vi) the final goods market clears, $Y_{ct} = C_{ct} + R_{ct}$, where $R_{ct} = \int_0^1 \sum_{i=1}^2 R_{ijct}dj$ is aggregate innovation investment;
(vii) $\int_0^1 \sum_{i=1}^2 (\omega_{ijFt}\tau_F p_{ijFt} y_{ijFt})dj = \int_0^1 \sum_{i=1}^2 (\omega_{ijHt}\tau_H p^*_{ijHt} y^*_{ijHt})dj$, i.e., balanced trade in intermediate goods;
and (viii) $\mu_{\boldsymbol{m}t}$ and Q_{ct} evolve as specified and are consistent with firms' choices of x_{ict}.

3.1 Model Mechanism

In this section, I illustrate how intermediate good firms make decisions. The proofs for propositions are relegated to Appendix.

3.1.1 Intermediate Firm Static Production Decision

Proposition 2. *Given the wage rates w_{ct} and aggregate revenue $P_{ct}Y_{ct}$ in each country, Home leaders' (followers') market shares and production profits are bounded and weakly-increasing (weakly-decreasing) in the domestic technology gap, and concave (convex) in the domestic technology gap if the domestic technology gap is large enough; Home (Foreign) firms' market shares and production profits are bounded and weakly-increasing (weakly-decreasing) in the global technology gap, and concave (convex) in the global technology gap if the global technology gap is high enough, given the other two technology gaps, $c \in \{H, F\}$. The Home firm's market share is increasing in the Foreign wage rate w_{Ft} and the trade cost τ_F given the technology gaps.*

Proposition 2 shows that a larger domestic technology gap m_c (i.e., the leader has a larger domestic technological advantage) implies the leader has higher productivity, market share, markup, and profits than the domestic follower. Similarly, a larger global technology gap m_G (i.e., Home has a larger global technological advantage) indicates Home firms have higher productivity, markup, and global market shares than Foreign firms. It can be numerically shown that firms with higher productivity relative to their competitors export a larger share of their output. Consequently, leaders have higher export intensity than domestic followers, and firms with a larger global technology gap have higher export intensity.

Proposition 2 also implies that the bounded production profit space, a result of market power, will eventually reduce the *extra* production profits from innovation to zero given the country's aggregate revenue. As a result, firms' innovation incentives diminish as they grow to a certain size.

Proposition 3. *Intermediate goods firms' scaled production profits $\Pi_{ict}(\boldsymbol{m})$ are functions of the technology gaps $\boldsymbol{m}$, trade cost τ_c, relative wage $\frac{w_{Ft}}{w_{Ht}}$, and relative aggregate expenditure $\frac{P_{Ft}Y_{Ft}}{P_{Ht}Y_{Ht}}$,* where $\boldsymbol{m} = \{m_H, m_F, m_G\}$, $c \in \{H, F\}, i \in \{1, 2\}$.

Proposition 3 indicates that when two countries are symmetric, relative market size $\frac{P_F Y_F}{P_H Y_H}$ and relative wage $\frac{w_F}{w_H}$, the two general equilibrium forces, do not matter for firms' scaled production profits $\Pi_{ict}(\boldsymbol{m})$. However, when two countries are asymmetric, they affect firm scaled production profit, and hence firm innovation incentives as shown in equations (3.7) and (3.9).

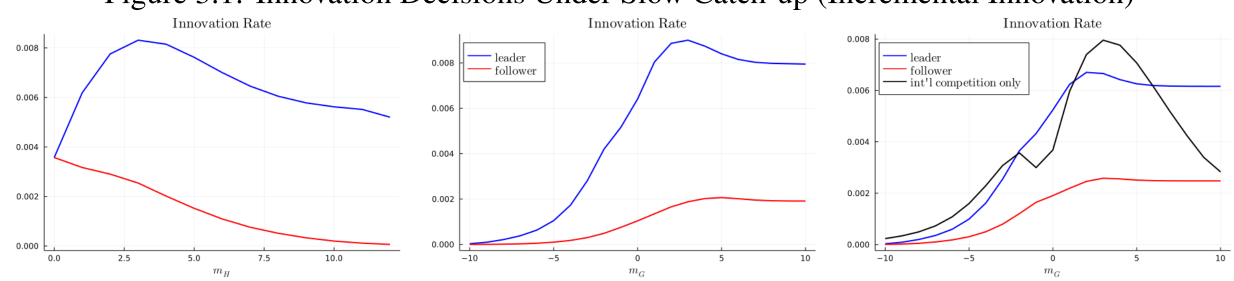
Proposition 4. *When there is an increase in foreign production profits, resulting from an increase in either foreign market share or relative aggregate expenditure $\frac{P_F Y_F}{P_H Y_H}$ (market size effect), the foreign production profits of leaders increase more than those of followers. When there is a decrease in domestic production profits due to a reduction in domestic market share (import competition effect), the domestic production profits of leaders decrease more than those of followers.*

Proposition 4 is informative for analyzing the effects of globalization as detailed later.

3.1.2 Intermediate Firm Dynamic Innovation Decision

For expositional simplicity without loss of generality, I assume two countries are symmetric, where each industry-country pair has two firms of equal mass ω_{ijct}. These firms are identical if they share the same productivity. As detailed in section 4.1, the data supports a model where firms primarily catch up with leading firms slowly. Therefore, I first examine the mechanism under *slow catch-up*. Even if the quick catch-up probability is positive, as long as it is sufficiently small the mechanism remains similar. There are three noteworthy results in Figure 3.1, as discussed below.

Figure 3.1: Innovation Decisions Under Slow Catch-up (Incremental Innovation)



(a) over domestic technology gap (b) over global technology gap (c) international competition only

Notes: This figure illustrates how Home innovation varies with technology gaps, assuming slow catch-up only: $\phi_c = \delta_c = 0, c \in \{H, F\}$. Panel (a) plots example Home innovation decisions in terms of Home's domestic technology gap m_H, given the global technology gap m_G and Foreign's domestic technology gap m_F are both 6. Panel (b) plots Home innovation decisions in terms of the global technology gap, given $m_H = m_F = 6$. Panel (c) compares Home innovation decisions in the absence of domestic competition with those in the presence of domestic competition.

Dual inverted-U shapes. Home innovation rates exhibit an inverted-U shape in both the domestic and international markets. This pattern aligns with existing strategic innovation models that consider small innovation step sizes (e.g., Akcigit and Ates (2023), Liu et al. (2022)). When firms have a small technological advantage relative to their competitors, they are motivated to innovate in order to "escape competition." However, once the technological advantage of leading firms becomes significant, backward firms are discouraged from innovation, as they are unable to bridge the gap. Firms with large technological leads also reduce their innovation efforts due to diminishing returns to escaping competition. Proposition 2 provides insights into this mechanism. Since firm value is driven by production profits, the shape of the value function is influenced by the production properties (see Figure A.1 for a numerical example). Thus, the additional value derived from successful innovation, which determines innovation incentives, relies on the extra profit it generates. The weakening of innovation incentives for leading firms as they grow is linked to the concavity and finite nature of profits relative to the size of the economy, i.e., $x_{1Ht} = \left(\frac{(v_{1Ht}(m_H+1,m_F,m_G+1)-v_{1Ht}(m_H,m_F,m_G)}{\alpha_{1H}}\right)^{\frac{1}{\gamma_{1H}-1}}$ converges to 0 as m_H and m_G increases to certain values. Conversely, the innovation decision of followers implies that $x_{2Ht} = \left(\frac{(v_{2Ht}(m_H-1,m_F,m_G)-v_{2Ht}(m_H,m_F,m_G)}{\alpha_{2H}}\right)^{\frac{1}{\gamma_{2H}-1}}$. Since the value of followers decreases and eventually becomes convex with respect to the domestic gap m_H, followers who are further behind (facing larger values of m_H) innovate less as they recognize additional innovation efforts yield diminishing benefits and the likelihood of surpassing the leaders decreases.[30]

International inverted-U shape peaks later. As firms increase their technological advantage, they experience fewer diminishing returns and reach the top of the inverted-U later in the international market than in the domestic one. This stems from facing stiffer competition and having more chances to improve market share and profits in the international market. When a Home leader innovates to increase the domestic technology gap, it gains market share and production profits from Home followers, while increasing the global technology gap m_G allows it to win profits from both Foreign leaders and Foreign followers. Consequently, the decreasing part of the inverted-U is less likely to be observed in the international market compared to the domestic market. This mechanism is supported by the data discussed in section 4.1.

Domestic competition flattens international inverted-U shapes. Suppose there is no strategic domestic competition, meaning that each country-industry pair has only one firm. In this scenario, Home firms place more emphasis on foreign competitors. They gain more from enhancing their global technological advantage, as the entire payoff goes to the unique Home firm instead of being divided among Home leaders and followers. Panel (c) in Figure 3.1 illustrates that Home firms initially have a stronger motivation to escape competition and experience diminishing innovation incentives at a faster speed as the global technology gap increases in the absence of domestic competition. With domestic competition, foreign competition is less harmful when firms have weak innovation incentives (when m_G is high), but stimulates less innovation when firms have a strong motivation to escape competition (when m_G is low).[31] The first result in Proposition 5 theoretically rationalizes this flattened international inverted-U shape due to domestic competition.

Proposition 5. *In a simplified model featuring two symmetric countries, which (i) abstracts from trade costs, (ii) sets the maximum global technology gap to one, and (iii) assumes a domestic competitive fringe in each country that occupies a certain market share, the following results hold:*
(a) the domestic competitive fringe flattens the international inverted-U shape, i.e., $x(m_G = 0) - x(m_G = -1)$ decreases as the market share of the domestic competitive fringe increases;
(b) as $\iota \to 1$, international knowledge diffusion reduces growth; the more if weaker domestic competition, lower initial global technological advantage, or the larger increase in international knowledge diffusion.

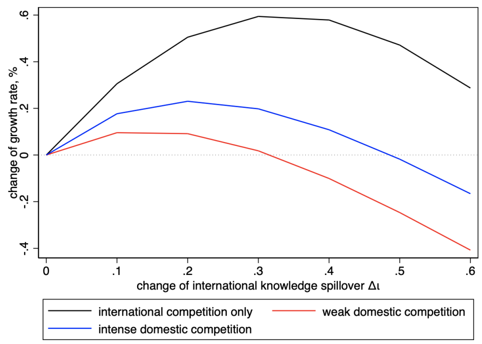
[30] Home innovation decisions in terms of Foreign's domestic technology gap m_F are in Figure A.2.

[31] Similarly, without international competition, Home firms place more emphasis on domestic competitors. Consequently, they have a stronger motivation to escape competition initially and then experience diminishing innovation incentives at a faster speed as the domestic technology gap increases. With foreign competition, domestic competition is less harmful when firms have diminishing innovation incentives (when m_H is high).

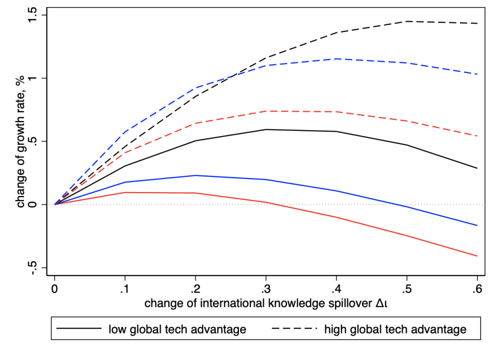
3.1.3 Effects of International Knowledge Diffusion

My model provides a new picture on how the effects of increasing international knowledge diffusion vary with (i) the magnitude of the increase in such diffusion, and (ii) the initial technological distance among firms both within and across countries.

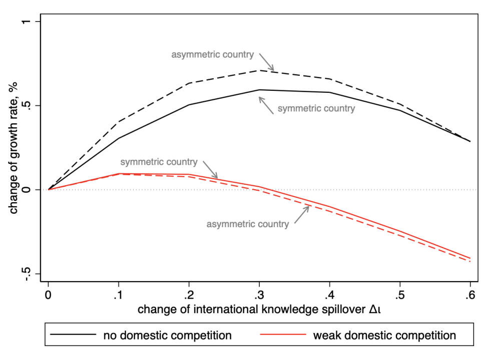
Figure 3.2: Growth Effect of International Knowledge Diffusion Under Slow Catch-up



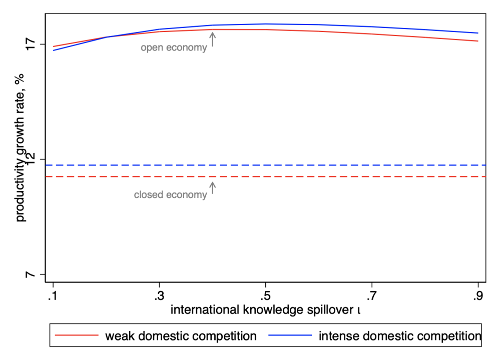
(a) Role of initial domestic competition



(b) Role of initial global tech advantage



(c) Role of market size effect



(d) Role of trade openness

Notes: This figure shows the change of aggregate productivity growth rate under various changes in the international spillover ι. Panel (a) plots under three model scenarios in which two countries are symmetric: no domestic competitors (black), weak domestic competition that features a high technological distance between leaders and domestic followers before the change of international spillover (red), and intense domestic competition that features a low technological distance between leaders and domestic followers before the change of international spillover (blue). Based on Panel (a), Panel (b) adds another three model scenarios but with a high global technological advantage before the change of international spillover (dashed). Based on Panel (a), Panel (c) additionally plots under an asymmetric country setup where the Foreign country is less productive than the Home country, and the market size effect arises from general equilibrium forces. Based on Panel (a), Panel (d) plots growth rate under different magnitudes of international knowledge spillovers in an open economy with two symmetric countries (solid) and a closed economy (dashed).

When two countries are symmetric, the increasing international knowledge spillover, modeled by an increasing ι, directly influences firm value, thereby affecting firm innovation incentives and growth. Panels (a) and (b) in Figure 3.2 show three results. First, there is nonlinear effect of international knowledge diffusion increase on aggregate productivity growth. When the increase in such diffusion is small, firms are likely to loose global technological advantage, and have relatively strong escape competition motive, leading to growth increase. While when the increase in such diffusion is large, firms are disincentivized to do innovation as they find little hope of maintaining global technological advantage.

Second, domestic competition reduces the growth effect of international knowledge diffusion. The weaker the initial domestic competition, captured by larger technological distance between leaders and domestic followers, the smaller growth effect of international knowledge diffusion. This is because firms place less emphasis on foreign competitors when they face domestic competition, and hence have less escape foreign competition motive. This result is consistent with the previously mentioned mechanism that domestic competition flattens international inverted-U curve.

Third, higher initial global technological advantage before the international knowledge diffusion increase, more positive growth effect of international knowledge diffusion. This is because, when a country has high initial global technological advantage, firms slack off due to diminishing returns to escaping competition. The increase in the international knowledge diffusion increases their escape foreign competition motive.[32] Note that even though two countries are symmetric, the fraction of industries that is neck-and-neck could be high or low. When a country has limited neck-and-neck industries (and hence many industries with higher productivity level than the other country) before the change of international knowledge diffusion, I call this country has high initial global technological advantage.

As highlighted by Proposition 3, when two countries are symmetric, relative market size $\frac{P_F Y_F}{P_H Y_H}$ does not matter for firm innovation incentives. However, when Foreign is less productive than Home, the increasing international knowledge spillovers increase the relative productivity of Foreign, which in turn generates a higher final demand $P_F Y_F$ via general equilibrium effects, leading to a higher relative market size faced by Home and hence higher scaled production profits. As Foreign's relative productivity rises, so does its relative wage, raising production costs. This reduces Foreign firms' market share while boosting Home firms' market share and scaled production profits. I define the *international business stealing effect* of increasing international knowledge diffusion as the effect on innovation incentives holding relative wage and relative market size (general equilibrium forces) constant at the initial international knowledge diffusion level. I define the *market size effect* of increasing international knowledge diffusion as the effect due to the increase in scaled production profits via general equilibrium forces. The market size effect of international knowledge diffusion only exists in an asymmetric country setup.

Panel (c) in Figure 3.2 shows that in the absence of domestic competition, the market size effect of increased international knowledge diffusion could strengthen its positive growth effect. While in the presence of domestic competition, this market size effect could amplify the negative growth effect. This is because, as highlighted by Proposition 4, larger market size increases leaders' production profits and hence innovation by more, which increases technological distance relative to domestic followers, leading to that domestic followers are discouraged from innovation and leaders reduce their innovation efforts due to diminishing returns to escaping competition. That is, firms are more concentrated in the decreasing part of domestic inverted-U curve.[33]

The potential negative effect of international knowledge diffusion does not mean that turning from openness to closeness yields higher growth. Panel (d) in Figure 3.2 shows that under any magnitude of knowledge diffusion, open economy grows faster than close economy, as profits from

[32] Explained through the international inverted-U shape, firms are concentrated in the decreasing part of the inverted-U initially, but the increasing international knowledge diffusion shifts firms' distribution to the top of the inverted-U shape, or even the increasing part of the inverted-U shape.

[33] Behind the aggregate impact of the international business stealing effect due to increased international knowledge diffusion, there are heterogeneous effects, as shown by Panel (b) in Figure A.4. Global leaders with close competitors (m_G larger than but close to 0) find it harder to maintain their global technological advantage, expect lower future profits, and innovate less. While global leaders without close competition (m_G high) innovate more to escape foreign competition.

selling to foreign market are huge, which incentives firms to do innovation. The potential negative effect of international knowledge diffusion just implies that, in the presence of trade openness, increasing international knowledge diffusion leads to lower growth than the initial steady state.

Macro implications beyond productivity growth. As discussed, firms' innovation responds asymmetrically to the change in international knowledge diffusion, depending on their technological distance within and across countries. The uneven firm growth, in turn, reshapes technological distance between firms. Given the one-to-one mapping between the technological distance and market share, a lower technological distance relative to foreign competitors decreases firms' global output share, and a higher technological distance between leaders and domestic followers increases leaders' market share relative to domestic followers, i.e., domestic concentration level.

3.1.4 Effects of Trade Cost

Numerical results demonstrate that decreasing trade cost increases firms' foreign market share (and hence foreign profits) but reduces domestic market share (and hence domestic profits) due to consumers' love-of-variety. This is consistent with a large class of trade models (e.g., Melitz (2003)). Furthermore, Home firms with a higher global technological advantage m_G have a higher export intensity. Therefore, an increase in foreign profits is more likely to compensate for a loss in domestic profits. I define the *market size effect* of trade cost reduction as the effect due to the increase in scaled production profits, and define the *import competition effect* of trade cost reduction as the effect due to the decrease in scaled production profits. Therefore, firms with higher m_G are more exposed to the market size effect than the import competition effect.

As indicated by Proposition 3, the declining trade costs influence firm innovation incentives by affecting production profits both through the trade cost itself and general equilibrium forces. According to Proposition 4, leaders experience a larger change in production profits than their domestic followers. A larger change in production profits typically leads to a larger change in innovation incentives. Panel (a) in Figure A.4 shows that the market size effect, which mainly affects firms with high m_G, results in a larger increase in innovation incentives for leaders than for followers. Conversely, the import competition effect, which mainly affects firms with low m_G, results in a larger reduction in innovation incentives than those of followers.[34] The aggregate impact on growth depends on the relative strength of market size effect and import competition effect.

3.1.5 Alternative Model Assumptions and Model Extensions

If quick catch-up. Panel (a) in Figure A.3 shows that if there is quick catch-up in domestic markets, followers innovate more as they fall further behind their domestic leader (face a larger m_H). According to the innovation decision of Home followers, $x_{2Ht} = \left(\frac{v_{2Ht}(0,m_F,m_G)-v_{2Ht}(m_H,m_F,m_G)}{\alpha_{2H}}\right)^{\frac{1}{\gamma_{2H}-1}}$, since follower value decreases with m_H, followers that are further behind have higher innovation rates due to the larger benefits from additional innovation. However, leader innovation remains similar to the slow catch-up case due to the concavity and finite nature of profits relative to the size of the economy. Analogously, when there is quick catch-up in international market, firms further behind the global frontier have higher innovation rates, as shown by Panel (b) in Figure A.3.[35] The aggregate growth effect of international knowledge diffusion is discussed in section 4.5.1.

[34] The market size effect and import competition effect on innovation do not monotonically increase with m_G due to strategic interactions among firms.

[35] The innovation incentives over the other two technology gaps are similar to the slow catch-up case.

Extensions and estimations. The model mechanisms and quantitative results are robust to various modeling extensions and alternative estimations, as detailed in Appendix B.

4 Data, Measurement, And Quantitative Analysis

I document firm variations in innovation across technology gaps in the data and employ these findings to estimate the model. I then explore the aggregate implications of increasing international knowledge spillovers, provide evidence for the model mechanism, and offer additional discussions on key model elements, policy implications, and other secular trends within the model.

4.1 Empirics for Firm Innovation over Technology Gaps

Due to data limitations, my focus is on OECD countries rather than developing ones. I do *not* interpret the empirical patterns as *causal* evidence, but as correlations that help discipline the model. As the U.S. data covers only public firms while the data for European countries is nearly nationally representative, the innovation patterns over technology gaps for U.S. firms are not used for model estimation. Instead, they serve as additional evidence to validate the model. In Appendix D.1, I explain how estimating the model using the U.S. data potentially affects the results.

4.1.1 Variable Construction

Technology gaps. As detailed in section 2.1, I use leaders' sales shares and global output shares as measures of the domestic technology gap across firms in an OECD country and the global technology gap between an OECD country and ROW.

Innovation incentive. Based on the patent data constructed in section 2.1, I use patent citations of newly granted patents every year (and the number of newly granted patents as a robustness check) to represent firm innovation rate. I assign a value of 0 for observations without patents or citations, effectively assuming that firms that do not innovate or fail to file a patent after innovation investment have a zero probability of successful innovation. This does not mean such a firm has no patents every year. Many firms patent infrequently, consistent with prior findings. I then standardize the innovation measure by demeaning and dividing it by the standard deviation among all firms.

Ideally, the private value of the patent to the firm would discipline the model since this directly governs the firm's innovation. However, obtaining privately-held patent values across many countries is challenging. The evidence documented by Kogan et al. (2017) showing that patent value is strongly correlated with the citation-weighted number of patents helps alleviate concerns over using patenting or patent citations to discipline firms' innovation incentive in the model.[36]

4.1.2 Empirical Facts and Robustness

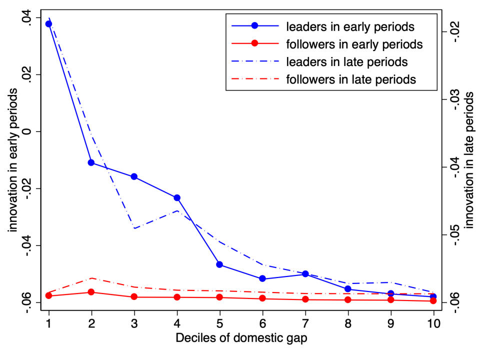
I proceed in three steps. First, I generate deciles of the constructed country-industry-level technology gaps that remain constant over time. Second, I calculate the weighted average of measured innovation for leaders and followers separately within each decile. The weight is determined by industry output and firm sales, which aligns with Autor et al. (2020a). The weighted average ensures that the results are not skewed towards small firms. This alleviates the concern regarding the inclusion of many small non-patent firms that have a limited market share and minimal aggregate implications. Third, I present the results separately for early (before 2005) and late periods (since 2005). Figure 4.1 illustrates two facts in Europe, with U.S. findings presented in Appendix E.2.

[36] Hall et al. (2005) also reveal that the number of citations a patent receives is a fine indicator of the patent's worth, increasing the market value of a firm at an increasing rate as the number of citations go higher.

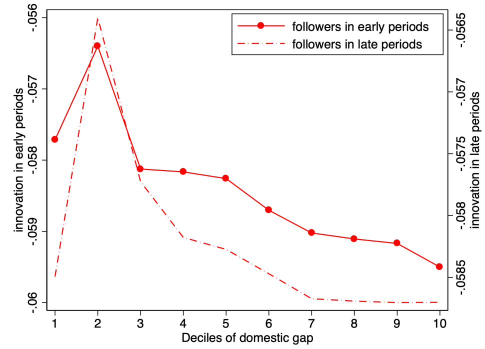
Fact 1. Innovation mostly decreases with the domestic technology gap but increases with the global technology gap. OECD firms innovate less as leaders' technological advantage over followers grows, or as their global technological advantage declines.[37]

Fact 2. These patterns qualitatively hold throughout the sample. Figure E.4 in Appendix further shows that the results are not driven by the financial crisis.

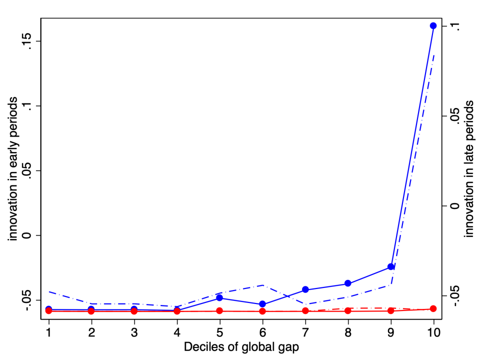
Figure 4.1: Standardized Number of Patent Citations: All European Firms



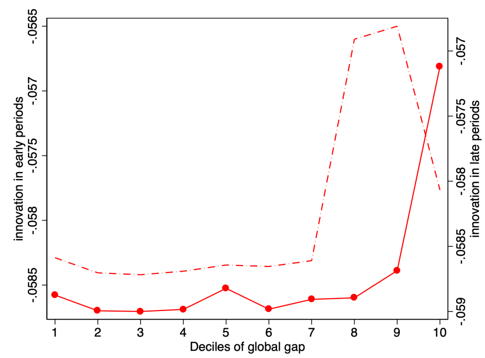
(a) leader over domestic gap



(b) follower over domestic gap



(c) leader over global gap



(d) follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis on the left (right) denotes the standardized number of citations of all firms in early (late) periods in OECD countries. To standardize number of citations, I subtract the mean and divide by the standard deviation across all firms. The domestic technology gap is computed as leaders' sales share within an industry-country pair. The global technology gap is measured as one country's global output share in an industry. The blue (red) line represents leaders (followers). The solid (dashed) line represents the early (late) period. The early period refers to the years between 1999 and 2004, while the late period refers to the years between 2005 and 2015.

Connection with the existing literature. My facts are related to the dynamic competition literature on "inverted-U" pattern of innovation across technology gaps. My results show that leaders have had a significant technological advantage over domestic followers, leading to a concentration of firms in the decreasing part of the "inverted-U" in domestic markets, while they are mainly situated on the increasing part in the global market. In Figure E.2 in the Appendix, I show that using data from the 1970s (only U.S. data is available in this period), firms are primarily concentrated in the increasing part of the "inverted-U" in the domestic market. Therefore, my empirical findings reveal that firms have shifted to the decreasing part of the "inverted-U" in the domestic market.[38]

[37] Leaders also receive more citations than followers when considering all their patents, which is captured by the model setup that leaders generate more knowledge spillovers.

[38] This is consistent with previous findings that firms are mainly concentrated in the increasing part of the "inverted-U" in the domestic market (e.g., Aghion et al. (2005), Cavenaile et al. (2019)), as evidenced by

Existing research (e.g., Akcigit and Kerr (2018), Acemoglu et al. (2018)) uses *within-industry* variation to demonstrate that smaller firms, contingent on successful patent filings, exhibit higher innovation intensity and are more likely to undertake "radical" innovation. This is further corroborated by my data, as shown in Table E.1 in Appendix. However, I utilize *cross-industry* variation to document firm innovations over technology gaps.

Robustness Check. Most results are qualitatively robust to using non-patent measures to address the concern that not all firms depend on patents for growth, using patent stock to measure technology gaps, and using intangibles to approximate innovation input. More are in Appendix E.2.

4.2 Parameterization for Balanced Growth Paths (BGPs)

I interpret the Home country as *an advanced OECD country* (OECD) and the Foreign country as *the rest of the world* (ROW) from the perspective of this advanced OECD country. For simplicity and without loss of generality, I conduct a steady state analysis by comparing two BGPs. While all countries maintain the same growth rate along the BGP, the reduced TFP level difference across countries and the decrease in the OECD's global output share in BGP can be attributed to the faster growth of ROW during the transition.

I set the innovation cost parameters and the market size parameter L_c to generate a realistic global technology gap and output share difference between OECD and ROW while minimizing cross-country differences for simplicity. Other parameters are estimated to match OECD data.[39] I parameterize the initial BGP equilibrium to the 1995–2004 data (1990s) and reestimate parameters to pin down the new 2005–2015 (2010s) BGP equilibrium, given data availability.

4.2.1 Initial BGP

I. Externally estimated parameters. The fraction of leaders within a country-industry is set to one percent, consistent with the way I define leaders empirically, and all other firms are followers. The OECD labor force is normalized to 1. The innovation cost function is quadratic with $\gamma_{ic} = 2$, a common estimate in the empirical innovation literature (cf., Acemoglu et al. (2018)). I set the discount factor ρ to match the OECD interest rate from the World Bank. For simplicity, the demand shifters $(\omega^{b}_{ijct}, \omega^{*b}_{ijct})$ are set to 1.[40]

II. Internally estimated parameters. The remaining parameters are pinned down to match salient data moments, as shown in Table 4.1. Although these parameters are jointly determined using the simulated method of moments technique, some parameters are closely related to certain specific moments, as detailed below.

data from the 1970s.

[39] In the aggregate datasets for parameterization, the advanced OECD country is defined as a GDP-weighted average of the 24 countries that joined the OECD before 1974: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The "rest of the world" is defined as the GDP-weighted average of countries covered in the 2021 OECD input-output tables, including all 38 OECD countries and 28 non-OECD countries/regions. The GDP weight is time invariant. The parameterization results are robust to using export-weighted averages across countries. In the ORBIS datasets, the advanced OECD country is defined as the industry output weighted average of the 12 European countries.

[40] I include these shifters to better match the data, as in some of the model extensions detailed later.

i. Aggregate variables. The labor force in ROW L_F is tightly linked to OECD's global output share; a larger L_F indicates a smaller OECD global output share. The within-industry elasticity of substitution across intermediate goods ϵ is set to target the aggregate markup estimated by De Loecker et al. (2020), which suggests markups for U.S. public firms in the 1990s ranged from 1.2 to 1.3.[41] The productivity step size λ is set to target the aggregate TFP growth rate in the OECD. The trade iceberg cost τ is set to target OECD export intensity, measured by total exports as a share of GDP. As is standard, a higher trade iceberg cost indicates a lower export intensity. The innovation cost scale parameters α_{1H} and α_{1F} are estimated to match the R&D to GDP ratio in the OECD and ROW in the data.[42]

ii. Innovation over technology gaps. I use Figure 4.1 to discipline firm innovation over technology gaps, consistent with Cavenaile et al. (2019). As shown in Figure 4.2, the innovation incentives of leaders and followers decrease as the domestic technology gap widens or as the global technology gap narrows. This aligns with the mechanism that there are fewer diminishing returns in the international market than in the domestic market, and the assumption of *slow* catch-up. As highlighted by section 3.1, the domestic and international quick catch-up probabilities, ϕ_c and δ_c, *uniquely* demonstrate that innovation can increase as firms move further away from the domestic or global frontier, in comparison to other parameters. Followers' innovation cost parameters α_{2H} and α_{2F} differ from leaders', affecting their innovation over technology gaps. I therefore use these parameters to match the standardized innovation rates over measured technology gaps to the data. In particular, I compute the difference between the 10th percentile and 90th percentile of measured innovation by OECD leaders' market share and OECD's industry global output share for OECD leaders and followers, in both the model and the data.

iii. Knowledge spillovers. Following the literature, knowledge spillovers explain the relevant data moments that cannot be solely attributed to firm innovation. Although all moments are jointly calibrated and interrelated, the *international knowledge spillover* parameter ι is closely associated with OECD TFP relative to ROW, consistent with existing papers (e.g., Prato (2024)). A larger ι means ROW is more likely to receive spillovers, narrowing the productivity gap with the OECD. While this approach to disciplining international spillovers is standard, two potential issues arise which I address through two methods. First, relative productivity between countries is not only affected by international knowledge spillovers but also other forces such as financial development, labor markets, or national policies. Therefore, I construct targeted country TFP by controlling for several competing channels, as detailed in Appendix G. Second, though consistent with other papers (e.g., Akcigit and Ates (2023)), using a single parameter ι to model international knowledge spillovers may not be justified by the data. In Appendix D.3, I use the industry-level variation in relative productivity between countries to show that ι can replicate the entire distribution of relative productivity across industries. Moreover, increasing ι can replicate the change of the distribution over time in the data, indicating the simple parameterization of international spillovers is not obviously lacking in depth. Furthermore, I discuss how my results are either robust or strengthened by alternative ways of modeling knowledge spillovers, as detailed in section 2.2 and Appendix B.

[41] The computation of the aggregate markup in the model is a revenue-weighted harmonic mean of firm markups, as discussed in Edmond et al. (2015).

[42] The data for the OECD global output share is from the 2021 OECD input-output table. The data for export intensity and R&D to GDP ratio are from the World Bank. The aggregate TFP growth rate is from the Penn World Table 9.1.

I use the OECD leader sales premium, which is defined as the log sales difference between leaders and followers, to discipline the *domestic knowledge spillover* parameter κ, similar to existing work (e.g., Liu et al. (2022)). A larger κ means followers are more likely to receive spillovers and hence reduce the technology gap and leader sales premium. When constructing the leader premium each year, I control for industry-country fixed effects.

4.2.2 New BGP

I reestimate all internal parameters to pin down the new BGP. The decrease in the trade cost τ and increase in international knowledge spillovers ι capture two forces of fast growing ROW (or referred to as two forces of globalization). Several other parameter changes capture some secular trends: the decrease of κ indicates declining domestic knowledge spillovers (Akcigit and Ates (2023)), the decrease in ρ represents a declining real interest rate (Liu et al. (2022)), and the increase in the innovation cost α_{ic} captures the fall in research productivity (Bloom et al. (2020)).

4.2.3 Model Fit and Connection with Previous Estimates

Table 4.1 lists the values of all estimated parameters and the actual and simulated moments for estimation. The estimated international knowledge spillover ι increases by a factor of five from the initial to the new BGP. Although it is difficult to directly justify this magnitude, it falls within the range of related data observations. Specifically, the non-OECD citation share, which serves as a lower boundary of knowledge transfer, doubles over time, as suggested by section 2. Holmes et al. (2015) document in their Table 5 that the technology capital transferred by multinationals to China increased by a factor of 22, and to Brazil, Russia, and India by a factor of 6.5 over the same period.

Other key parameters are also consistent with the existing literature. First, the domestic spillover parameter is estimated to be larger than for international spillovers, in line with the existing literature arguing that knowledge spillovers are stronger within than across countries (see, e.g., Eaton and Kortum (1999), Keller (2002), Sampson (2023)). Second, the quick catch-up probability estimates are small, quantitatively similar to Akcigit and Ates (2023) and Akcigit et al. (2024). Third, ROW firms pay higher innovation costs than OECD firms, which reflects their relatively low innovation efficiency. However, the large differences in the innovation cost parameters are also driven by the large market size difference (or labor force difference) between OECD and ROW.

4.2.4 Sensitivity Analysis

Table D.1 summarizes the percentage change in each targeted moment in response to a 1% change in each internally estimated parameter, indicating that the internally estimated parameters are indeed closely related to certain specific moments discussed above.

4.3 Model Validation

I present two out-of-sample tests to assess the plausibility of the parameterization.

Firm Innovation over Technology Gaps. The model targets the 90-10 percentile difference in innovation as a function of technology gaps. Reassuringly, the overall patterns of innovation over technology gaps closely match the data, as shown in Figure 4.2.

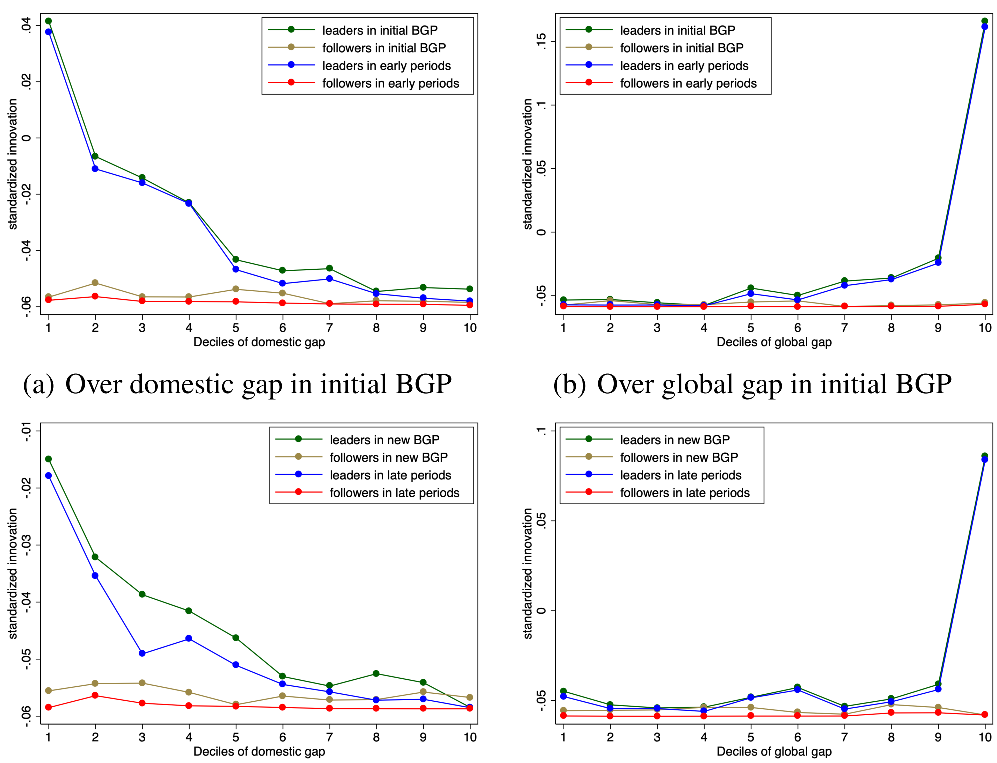
Industry Mass Distribution. Although not directly targeted, the entire distribution of OECD leader market shares among domestic firms and OECD firms' global output share closely match the data along both the initial and new BGPs. Figure 4.3 shows that over time, more and more industries have leaders with high domestic market shares, indicating an increase in domestic concentration,

Table 4.1: Parameterization and Targeted Moments

Parameter	Notation	Value: Initial BGP	Value: New BGP	Identification	Targeted Moments: Initial BGP Data	Initial BGP Model	New BGP Data	New BGP Model
External Parameterization								
Fraction of leaders	ω_{1c}	0.01	0.01	Empirical facts				
Home labor force	L_H	1	1	Normalization				
Innovation cost elasticity	γ_{ic}	2	2	Common estimates				
Discount factor	ρ	0.05	0.02	Real interest rate				
Internal Parameterization								
Panel A. Aggregate variables								
Foreign labor force	L_F	30	31.5	Mean global output share	0.06	0.06	0.03	0.03
Elasticity of substitution	ϵ	5	6	Aggregate markup	1.20-1.30	1.30	1.50-1.60	1.51
Productivity step size	λ	1.08	1.12	TFP growth rate,%	1.53	1.53	0.24	0.24
Trade iceberg cost	τ_c	1.91	1.83	Mean export intensity	0.17	0.17	0.24	0.24
Innovation cost scale	α_{1H}	18.73	35.92	R&D/GDP in OECD,%	2.27	2.30	2.46	2.46
	α_{1F}	109.56	217.37	R&D/GDP in ROW,%	1.91	1.87	2.19	2.21
Panel B. Innovation								
Innovation cost scale	α_{2H}	2.97	5.67	$\lvert$p10 - p90$\rvert_{1H}$ over domestic gap	0.041	0.040	0.042	0.041
	α_{2F}	7.83	15.11	$\lvert$p10 - p90$\rvert_{2H}$ over domestic gap	0.001	0.001	0.002	0.002
Domestic step size	ϕ_c	0.021	0.019	$\lvert$p90 - p10$\rvert_{1H}$ over global gap	0.025	0.026	0.022	0.022
International step size	δ_c	0.009	0.013	$\lvert$p90 - p10$\rvert_{2H}$ over global gap	0.001	0.001	0.002	0.002
Panel C. Knowledge Spillovers								
International spillovers	ι	0.01	0.05	Mean (OECD TFP/ROW TFP)	1.29	1.29	1.13	1.13
Domestic spillovers	κ	0.09	0.07	Mean leader sales premium	3.10	3.09	3.62	3.62

Notes: $i \in \{1,2\}, c \in \{H,F\}$. For the internal parameterization, all parameters are estimated jointly. The data moments are computed from advanced OECD countries unless specified.

Figure 4.2: Firm Innovation over Technology Gaps: Model vs Data



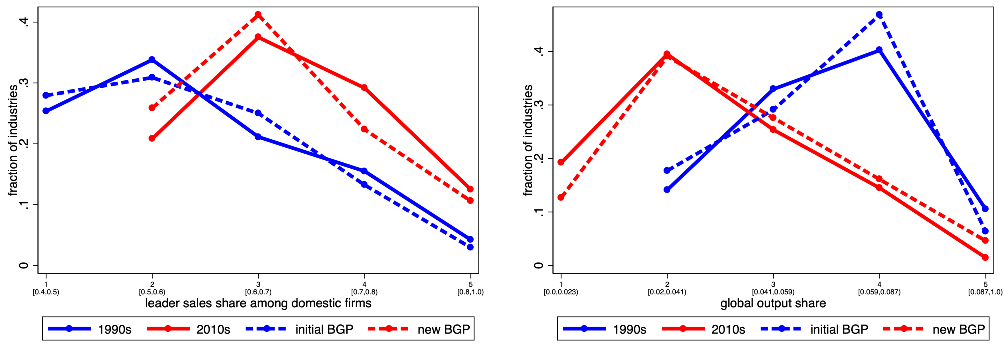
(a) Over domestic gap in initial BGP (b) Over global gap in initial BGP

(c) Over domestic gap in new BGP (d) Over global gap in new BGP

Notes: This figure presents the standardized innovation rate in the model (initial/new BGP) and standardized patent citations in the data (early/late period) for OECD. The X-axis partitions the range of measured technology gaps into 10 deciles. The Y-axis denotes the weighted average standardized innovation in each group. To standardize innovation rate in the model and number of citations in the data, I subtract the mean and divide by the standard deviation across all firms. The construction of technology gaps in both the model and the data is the same as Figure 4.1.

consistent with Bajgar et al. (2023) that addresses differences from Kalemli-Ozcan et al. (2022).[43] Meanwhile, more and more OECD industries are losing global output share. The successful replication of the industry mass distribution makes the model implications more convincing.

Figure 4.3: Industry Mass Distribution: Model vs Data



(a) OECD domestic concentration (b) OECD global output share

Notes: This figure presents the industry mass distribution over domestic concentration (i.e., leader sales share among domestic firms) and global output shares for OECD firms in both the model and the data. The X-axis partitions the range of X into 5 equal lengths. The Y-axis denotes the fraction of industries within each of the five groups. The solid line represents the data, and the dashed line represents the model. The blue line represents the early period in the data (1990s) and the model (initial BGP), and the red line represents the late period in the data (2010s) and model (new BGP).

4.4 Implications of Fast-Growing ROW

4.4.1 Implications for OECD and ROW

Figures 4.2 and 4.3 imply that over time the distribution of OECD firms over the domestic technology gap shifts to the right and the distribution over the global technology gap shifts to the left. As firm innovation decreases in the domestic technology gap and increases in the global technology gap, the moving distribution indicates an innovation slowdown.

Implications for OECD. The first two columns in Table 4.2 indicate that the model successfully captures OECD data. The third column of Table 4.2 isolates the impact of two forces of fast-growing ROW by altering the two related parameters from their initial BGP values to their new BGP values, with the others remaining at their initial values. It shows that TFP growth decreases. The increase in the domestic technology gap is consistent with the empirical evidence that the productivity gap between leaders and followers has increased. The decrease in the global technology gap is consistent with the observed decline in OECD TFP relative to ROW. The larger increase in the export premium compared to sales premium is due to the large increase in foreign market size which favors leader exports.[44]

Extensive or intensive margin? Is slower productivity growth, induced by the fast-growing ROW, driven by market reallocation across heterogeneous firms (i.e., extensive margin) or a reduction in firms' own innovation (i.e., intensive margin)? To investigate, I assume firms' innovation incentive given technology gaps in the new BGP is the same as in the initial BGP and compute the

[43]Based on Kalemli-Ozcan et al. (2022), Bajgar et al. (2023) find that the choice of industry denominator in concentration measures is important, and the OECD STAN database, derived from national accounts, can be suitably used to construct concentration measures.

[44]The leader premium in sales is computed from 12 OECD countries in ORBIS. The leader premium in exports is computed from France and Greece due to data limitations. To make these premiums comparable, the leader premium in exports is relative to sales in France and Greece.

change from the initial to the new BGP to isolate the contribution of the extensive margin. I then assume firms' distribution over technology gaps in the new BGP is the same as in the initial BGP and compute the change from the initial to the new BGP to isolate the contribution of the intensive margin. I find the extensive margin explains around 69% of the changes, while the intensive margin explains around 33%. The sum of the two margins exceeds 100% due to their interactions in general equilibrium. This finding makes the negative growth effect less surprising, as traditional models of heterogeneous firms suggest small firms grow faster than large firms, and reallocating market share to large firms can lead to a growth slowdown.

Table 4.2: Implications of Fast-Growing ROW (Globalization)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	on OECD											on ROW
	Data	Model	Model Decomposition									Model
			globalization	$\iota\uparrow$	$\tau\downarrow$	$\iota\uparrow$ IS	$\tau\downarrow$ MS	$\tau\downarrow$ IC	$\rho\downarrow$	$\kappa\downarrow$	$\alpha_H,\alpha_F\uparrow$	globalization
Panel A. Technology gaps												
ΔDomestic gap		1.33	1.15	1.14	0.01	-0.02	0.02	-0.01	0.24	0.61	-0.69	0.27
ΔGlobal gap		-1.61	-0.82	-0.82	-0.05	-0.96			0.17	0.14	-0.10	
Panel B. Uneven firm growth												
ΔLeader sales premium	0.52	0.52	0.44	0.39	0.01	-0.11	0.02	-0.01	0.09	0.15	-0.25	0.07
ΔLeader exports premium	0.91	0.92	0.81	0.81	0.002	-0.11	0.004	-0.002	0.26	0.49	-0.32	0.13
Panel C. Aggregates												
ΔTFP growth rate,%	-1.29	-1.30	-0.42	-0.42	0.00	-0.37			-0.001	-0.07	-0.92	-0.42
ΔDomestic concentration	0.09	0.09	0.07	0.06	0.01	-0.05			0.01	0.03	-0.03	0.02
ΔGlobal output share	-0.03	-0.02	-0.01	-0.01	0.00	-0.03			0.00	0.00	0.00	
ΔAggregate markup	0.30	0.21	0.14	0.08	0.05	-0.02			0.001	0.01	-0.01	0.01

Notes: The first two columns display the absolute changes in key variables of interest between the 1990s (initial BGP) and the 2010s (new BGP) for the OECD data (model). The changes in model variables from columns 3 to 5 and 9 to 11 result from individual parameter changes between their initial BGP values and new BGP values, while holding other parameters constant at their initial values. Columns 6 to 8 decompose the effects of globalization. Specifically, column 6 illustrates the international business stealing effect of the knowledge spillover force, while columns 7 and 8 demonstrate the market size effect and import competition effect of the trade cost force, respectively. Column 12 presents the changes in key variables of interest between the initial BGP and the new BGP for the ROW model economy. The domestic gap is the average $m_c, c \in \{H, F\}$, and the global gap is the average m_G in the model. The leader sales (exports) premium is the log sales (exports) difference between leaders and followers. The definition of other variables is in section 4.2.1.

Implications for ROW. As shown in column 12 of Table 4.2, long-run growth decreases because all countries share the same BGP in the model. The increase in domestic concentration is smaller than in OECD. This is because along the initial BGP, ROW is less concentrated compared to OECD and hence follower firms have relatively strong catch-up incentives, moderating domestic concentration. The initially less concentrated ROW market is driven by expensive ROW innovation which slows down the growth of firms, especially leaders. This is consistent with the facts discussed by Peters and Zilibotti (2021) that in richer economies firms are on average larger and the best firms grow more over time than in poorer countries, though our theoretical explanation is different.[45]

4.4.2 Decomposing the Forces of Fast-Growing ROW

The parameterized results suggest that fast-growing ROW leads to a rise in ROW's relative wage and aggregate expenditure. As discussed in section 3.1.3, this predicts that (i) the increased international knowledge spillover generates both a market size effect and an international business stealing effect; (ii) the decline in trade costs produces both a market size effect and an import competition effect; (iii) firms' responses vary across industries.

[45]Empirically, I find that less developed countries such as Hungary, Bulgaria, and Slovenia have experienced rising domestic concentration, consistent with the predictions of my model. They did not join the OECD before 1974 and hence are not considered advanced OECD countries in my quantitative analysis.

Columns 4 and 5 in Table 4.2 report the implications of changing each force in isolation. The declining trade costs predict a counterfactually smaller increase in the leader export premium compared to sales, driven by larger decreases in leader domestic markups relative to export markups. Constant TFP growth and global output shares indicate the tiny role of trade costs. The international knowledge spillover force dominates for two reasons. First, it generates a unique international business stealing effect, facilitating the growth of ROW and reducing the global output share of OECD. Second, it generates a larger market size effect by costlessly increasing ROW's productivity, boosting ROW's income and final demand.

I also find the distribution of OECD industries over their global output share changes differently in response to each force. Figure D.2 shows increasing international spillovers shifts the initial distribution to the left, consistent with the data, while decreasing iceberg costs disperses the initial distribution around its mean. The former showcases a cross-country *technological convergence* story. The latter is a *specialization* story, where OECD and ROW firms with initially high global technological advantages innovate more to reap higher export profits due to the relatively large market size effect, leading to industry technological divergence across countries.

I further decompose the effects of each force in columns 6 to 8 of Table 4.2 based on their definitions in section 3.1.3, highlighting two implications. First, the international business stealing effect hurts TFP growth more than the other effects. Second, the market size effect predicts a larger increase in innovation for leaders compared to followers, while the other two effects predict the opposite. Details are in Appendix D.5.

4.4.3 Sensitivity Analysis: Varying the Magnitude of Parameters

To address concerns that the implications of fast-growing ROW may be unique to specific changes in parameters, Table D.2 presents the results using a range of changes, demonstrating that the qualitative implications of fast-growing ROW remain consistent with the baseline results. It also highlights the intriguing non-linear impact of fast-growing ROW consistent with the model mechanism, with detailed discussion in Appendix D.4.

4.4.4 Transition Dynamics and Welfare

I conduct a quantitative analysis using steady-state comparative statics for simplicity, without loss of generality. Although all countries maintain the same growth rate along the BGP, fast-growing ROW reduces the TFP level difference between OECD and ROW and decreases the OECD's share of global GDP, which aligns with the data. The reduced TFP level difference can be naturally attributed to the faster growth of ROW during the transition.

However, transitioning between steady states can be lengthy. It is unclear if the model's long-run productivity growth prediction aligns with the productivity growth slowdown observed in the data. To this end, I calculate the model's transition dynamics in response to fast-growing ROW, implementing a gradual decrease in iceberg trade costs and an increase in international knowledge spillovers to match OECD export intensity and relative TFP between OECD and ROW in the first 20 years of a transition episode.

Figure D.3 illustrates that productivity growth initially surges, then declines rapidly towards the new steady state value after seven years. ROW productivity growth exceeds that of OECD, aligning with the data. Intuitively, OECD firms realize that fast-growing ROW will create larger foreign markets and hence larger profits, especially for leaders, which leads to surges in innovation investment and productivity growth. But over time, the general equilibrium forces that decrease innovation materialize, leading to a growth slowdown. ROW's higher growth stems from greater knowledge spillovers from a more productive OECD. In the long run, global productivity growth slows down, with all countries' growth rates depending on global leaders' innovation. Meanwhile, infrequent innovation leads to a gradual change in firms' relative productivity and slowly rising domestic concentration that does not reach its new steady state after twenty years.

I also find OECD welfare increases by 1% and ROW by 9%, in consumption equivalent terms, as specified in Appendix A.3, starting from the transition towards the new BGP. Welfare gains are front-loaded due to slower long-run growth.[46]

4.4.5 Evidence Validating the Model Mechanism

According to the model, industries with larger increases in export openness (more exposed to the market size effect) first have bigger increases in leader innovation and corresponding declines later. To show this, I track firms through the 20-year transition dynamics and use the model simulated data to run regressions using the initial and end periods of the transition. I run similar regressions in the data and find the data and model results are qualitatively consistent, as shown in Table D.7. Appendix D.7 shows that the data results are robust to alternative measures of innovation and are not driven by the financial crisis. It also includes an instrument for export openness that addresses endogeneity issues (motivated by Autor et al. (2020a)), and empirical evidence on import intensity to validate my findings. The summary statistics in Figure 2.1 are also consistent with model results.

These findings align with those of Aghion et al. (2018), which reveal that in French manufacturing, only the most productive firms boost innovation in response to increased foreign demand, while less productive firms innovate less. My findings further emphasize the dynamic effect in response to a larger foreign market size. Existing work such as Gutiérrez and Philippon (2020) and Ekerdt and Wu (2022) indicates that after the financial crisis, when the growth in export intensity slows down, domestic concentration also increases at a slower pace. This is consistent with the model mechanism. The model mechanism also aligns with established findings that industries becoming more concentrated tend to exhibit faster productivity growth, as noted in Autor et al. (2020b). This is because industries experiencing an increase in concentration are more influenced by the market size effect. Consequently, they initially experience a surge in innovation incentives.

4.5 Additional Discussion

4.5.1 The Role of the Main Model Elements

I highlight the role of each key model ingredient in quantifying fast-growing ROW effects using a BGP analysis. This also provides insight into potential strategies that could mitigate any productivity slowdown caused by strategic innovation.

Role of strategic domestic competition in an open economy. I shut down strategic domestic competition by collapsing each industry to one firm per country, making the model similar to Akcigit et al. (2018). A recalibrated model indicates that strategic international competition alone plays a minor role in driving down productivity growth, as shown in column 2 in Table D.3. This is due to the larger "escape-competition" innovation incentive of OECD firms when they focus more on foreign competitors, as explained in section 3.1.

[46]The estimate for welfare gains in the OECD can be treated as a lower bound, since accounting for unbalanced trade and the large current account deficits in OECD countries, which are absent in my model, would generate higher welfare gains.

Role of initial technology gaps. In column 5, I reduce the initial domestic technology gap to one-third of the baseline case, resulting in more OECD firms' innovation concentrating in the increasing part of the inverted-U in the domestic market. In column 6, I increase the initial global technology gap to three times the baseline level, causing more OECD innovation to concentrate in the decreasing part of the inverted-U in the international market. The recalibrated results in both scenarios demonstrate that fast-growing ROW shifts the distribution of OECD firms to the right over the domestic technology gap and to the left over the global gap. The negative growth impact of fast-growing ROW vanishes compared to the baseline model. This is due to the amplified incentive to escape competition in both domestic and international markets, as firms innovate more when the domestic technology gap widens and the global technology gap narrows. These results suggest that in the 1990s, the initial domestic technology gap was large enough and the initial global technology gap was small enough that the escape competition motive was limited.

Role of innovation step size. In column 3 of Table D.3, I assume a quick catch-up probability for domestic followers equal to 1 in both countries while keeping international catch-up unchanged from the baseline case. This means that followers have a higher innovation rate when they are further behind their domestic leaders, as assumed in Perla et al. (2021). The recalibrated results indicate that the baseline predictions on domestic concentration and productivity growth are overturned. This is because the market size effect of fast-growing ROW dominates and triggers a larger increase in innovation for followers compared to leaders. Due to quick catch-up, followers anticipate a much larger increase in export profits from globalization once they close the technology gap with leaders, leading them to innovate more. In column 4, I assume a quick international catch-up probability of 1 in both countries while keeping domestic catch-up the same as in the baseline case, so firms have higher innovation incentives when they have a smaller global technological advantage, similar to Akcigit et al. (2018). The recalibrated results show a positive growth effect of fast-growing ROW because OECD firms have a higher innovation rate as harsher foreign competition reduces their global technological advantage. This exercise highlights the importance of micro-founding firm innovation when assessing the macro implications of changes in market primitives.

4.5.2 Policy Implications

I provide three important insights to facilitate long-run growth. First, policymakers should consider the indirect effects on non-targeted markets and strike a balance between reducing foreign competition and promoting domestic competition. For instance, innovation subsidies and import tariffs aimed at reducing foreign competition may hinder growth by further weakening domestic competition, especially since domestic leaders benefit more from reduced foreign competition. Second, policies should vary according to technological distance among firms. Policy interventions might only be necessary when the technological gap between firms is so large that the escape-competition motive diminishes. Third, when reallocating resources to heterogeneous firms, both the current productivity level and future growth potential should be considered. Innovation policies that favor smaller (with lower productivity) innovative firms can be more effective than imposing taxes on productive domestic leaders, due to the higher growth potential of smaller firms.

Specifically, I introduce a set of unilateral policies for the OECD during globalization to assess potential remedies for the negative growth effect of globalization by comparing the initial BGP and new BGP.[47] Panel B in Table D.4 indicates three findings. First, innovation policies promoting domestic competition are more effective in increasing productivity growth than those reducing

[47] I consider innovation policy (subsidies to all firms or just followers), trade policy (export subsidies to

foreign competition. Second, innovation policies outperform trade and corporate tax policies in raising productivity growth since they directly impact firm innovation incentives, while others affect indirectly via changes in profits. Third, tariff increases that reduce foreign competition negatively impact productivity growth by weakening domestic competition and innovation incentives.

Policymakers could also consider policies around intellectual property rights or technology transfer. In Panel C of Table D.4, a policy that facilitates domestic technology transfer from leaders to followers (by imposing a domestic knowledge spillover κ five times larger than the baseline model) and a policy that reduces technology transfer from OECD to ROW (by reducing the international knowledge spillover ι to one-fifth of its baseline level) can both undo the negative growth effect of globalization because firms are less negatively affected by globalization-induced weaker domestic competition or harsher foreign competition. Although these technology transfer policies seem promising, I assume these transfers are costless. It is unclear how costly these policies would be or what policy levers affect technology transfer, questions I leave for future research.

4.5.3 Comparison with Other Secular Trends

The ninth through eleventh columns in Table 4.2 display the effects of three alternative trends in this model. Two notable findings emerge. First, these alternatives generate counterfactual predictions. The **declining real interest rate** and **declining domestic knowledge spillovers** disproportionately promote successful innovation among OECD firms, widening the global technology gap. This contradicts the observed convergence between OECD and ROW TFP. This discrepancy arises because OECD firms exhibit higher innovation efficiency than ROW firms. **The fall in research productivity** explains slower TFP growth but predicts a decrease in domestic concentration. This is because leaders are more sensitive to increases in innovation costs, as demonstrated by firms' profit function and innovation decision. Second, the quantitative explanatory power of fast-growing ROW (globalization) in *jointly* explaining aggregate variables of interest is stronger than all these alternatives. The explanatory power is not only from harsher foreign competition but also from a larger foreign market. Globalization uniquely generates broader markets than other forces and amplifies the economies of scale due to innovation.

My model also explains the trend that **OECD countries have experienced an increase in the R&D expenditure share of GDP** and **large firms account for a larger share of R&D expenditure over time** (see, e.g., Anderson and Kindlon (2019)). This is because my parameterization captures the fact that large firms have higher R&D expenditure, and model predicts that large firms account for a larger share of innovations over time.[48]

Two points are worth noting. First, the domestic knowledge spillover decline could be driven by globalization, as discussed in section 2.2. As the model predicts that the domestic knowledge spillover decline reduces TFP growth, the impact of globalization could be amplified if globalization results in a reduction of domestic knowledge spillover. Second, I take globalization as exogenously given but it is endogenous to technological change (e.g., trade cost decreases due to ICT improve-

followers, tariff increases), and corporate tax policy (profit taxes on leaders). All policies are balanced government transfer (equivalent to a 20% tariff increase). Policies that favor followers (subsidy to followers or tax on leaders) effectively aim to reduce "globalization-induced weaker domestic competition." Policies that favor all firms (subsidy to all firms or tariff increase) effectively aim to reduce "globalization-induced foreign competition."

[48] The World Bank data shows that both OECD and non-OECD countries have higher R&D-to-GDP ratios, with the latter increasing less than the former. My model captures this.

ment). I therefore do not rule out the possibility that the nature of technological change might be more important than trade cost effects (Kwon et al. (2024)). Nevertheless, explicitly examining the role of globalization is valuable for distinguishing between varying competitive dynamics across different markets, an aspect often neglected in studies on the nature of technological change.

5 Conclusion

My model provides a valuable framework for analyzing the interplay among trade, knowledge diffusion, innovation, and antitrust policies in the presence of strategic competition among firms both within and across countries. This is particularly crucial in today's global environment where balancing domestic competition with foreign market strategies has become essential. I calibrate the model to the OECD data and demonstrate how the increase in knowledge diffusion from OECD to non-OECD countries contributes to rapid growth in non-OECD. This diffusion boosts short-run productivity growth but could ultimately decelerate long-run growth across countries.

My analysis identifies several avenues for future research. First, my model could be used to study other factors driving non-OECD growth, such as policy reforms, and their effects on OECD economies. Second, my model implies that investigating optimal policies should take international knowledge spillovers into account. Specifically, the effectiveness of trade policy in improving welfare depends on whether knowledge spillovers are primarily embodied in, or disembodied from, trade flows. Third, my analysis suggests that the optimal level of domestic concentration may vary by country and may depend on its technological distance from the global leader. Fourth, while my macro-level implications reflect the average experience of industries across OECD countries, industry- or country-specific analyses remain possible and are left for future research.

Appendix—Proofs and Derivations

Proof of Proposition 1.

The aggregate Home productivity index is defined by Home leaders' productivity: $Q_{Ht} \equiv \int_0^1 \ln q_{1jHt} dj$.[49] Define the aggregate world productivity index by the global technology frontier in each industry j: $\tilde{Q}_t \equiv \int_0^1 \ln q_{1jHt} \cdot \mathbb{1}_{m_G \geq 0} dj + \int_0^1 \ln q_{1jFt} \cdot \mathbb{1}_{m_G<0} dj$. It is straightforward to show that $Q_{Ht} = \tilde{Q}_t + \int_0^1 m_G \ln(\lambda) \mathbb{1}_{m_G<0} dj$ given that $Q_{Ht} = \int_0^1 \ln q_{1jHt} \mathbb{1}_{m_G \geq 0} dj + \int_0^1 \ln(q_{1jFt} \frac{q_{1jHt}}{q_{1jFt}}) \mathbb{1}_{m_G<0} dj$. So $g_{Ht} \equiv \dot{Q}_{Ht} = \dot{\tilde{Q}}_t$ along a stationary equilibrium. $\dot{\tilde{Q}}_t$ is determined by the innovation of the global technology frontier in each industry j. Note that $\dot{\tilde{Q}}_t$ can be characterized based on the assumption that global leaders can only increase productivity by a uniform step size of λ. Within a time interval of Δt, the mass of productivity improvement realized in industries with $m_G \geq 0$ due to successful innovation of Home leaders is $\Delta t [\sum_{m_H=0}^{\bar{m}_H} \sum_{m_F=0}^{\bar{m}_F} \sum_{m_G=0}^{\bar{m}_G} x_{1Ht}(\boldsymbol{m}) \mu_t(\boldsymbol{m})]$. Notice that when two Home firms are neck-and-neck, both firms can drive up aggregate productivity through successful innovation. So the mass of productivity improvement realized in industries with $m_G \geq 0$ due to successful innovation by the other neck-and-neck Home firm within a time interval of

[49] Note that if two Home firms are neck-and-neck with $m_H = 0$, one of them is defined with $i = 1$, and the other is not considered in defining Q_{Ht}.

Δt is $\Delta t[\sum_{m_H=0}^{0}\sum_{m_F=0}^{\bar{m}_F}\sum_{m_G=0}^{\bar{m}_G} x_{2Ht}(\boldsymbol{m})\mu_t(\boldsymbol{m})]$. The mass of productivity improvement realized in industries with $m_G \leq 0$ due to successful innovation by Foreign leaders can be symmetrically characterized. Note that when $m_G = 0$, both Home and Foreign leaders can drive up aggregate productivity through successful innovation. Since the productivity improvement of global leaders has step size λ, we have $\tilde{Q}_{t+\Delta t} - \tilde{Q}_t = \Delta t[\sum_{m_H=0}^{\bar{m}_H}\sum_{m_F=0}^{\bar{m}_F}\sum_{m_G=0}^{\bar{m}_G} x_{1Ht}(\boldsymbol{m})\mu_t(\boldsymbol{m}) + \sum_{m_H=0}^{0}\sum_{m_F=0}^{\bar{m}_F}\sum_{m_G=0}^{\bar{m}_G} x_{2Ht}(\boldsymbol{m})\mu_t(\boldsymbol{m}) + \sum_{m_H=0}^{\bar{m}_H}\sum_{m_F=0}^{\bar{m}_F}\sum_{m_G=-\bar{m}_G}^{0} x_{1Ft}(\boldsymbol{m})\mu_t(\boldsymbol{m}) + \sum_{m_H=0}^{\bar{m}_H}\sum_{m_F=0}^{0}\sum_{m_G=-\bar{m}_G}^{0} x_{2Ft}(\boldsymbol{m})\mu_t(\boldsymbol{m})] \cdot \ln(\lambda)$.

Rearranging and taking the limit $\Delta t \to 0$, along the BGP we have $g_{Ht} = \dot{\tilde{Q}}_t = \{\sum_{0\leq m_H\leq \bar{m}_H}\sum_{0\leq m_F\leq \bar{m}_F}\sum_{m_G\geq 0}[x_{1H}(\boldsymbol{m})\cdot\mu(\boldsymbol{m}) + x_{2H}(\boldsymbol{m})\cdot \mathbb{1}_{m_H=0}\cdot\mu(\boldsymbol{m})] + \sum_{0\leq m_H\leq \bar{m}_H}\sum_{0\leq m_F\leq \bar{m}_F}\sum_{m_G\leq 0}[x_{1F}(\boldsymbol{m})\cdot\mu(\boldsymbol{m}) + x_{2F}(\boldsymbol{m})\cdot \mathbb{1}_{m_F=0}\cdot\mu(\boldsymbol{m})]\}\cdot\ln(\lambda)$.

$g_F = g_H$ can be seen from $Q_{Ft} \equiv \int_0^1 \ln q_{1jFt}dj = Q_{Ht} + \int_0^1 \ln(\frac{q_{1jFt}}{q_{1jHt}})dj$. Notice that $\int_0^1 \ln(\frac{q_{1jFt}}{q_{1jHt}})dj = \sum_{\boldsymbol{m}} \ln(\frac{q_{1jFt}}{q_{1jHt}})\mu_{\boldsymbol{m}}$ depends on the distribution of firms and relative productivity between Home leaders and Foreign leaders, and is constant in BGP equilibrium.

Proposition A.1. *Along BGP the growth rate of aggregate output Y_c and consumption C_c is $2g_c$, the growth rate of the aggregate price index P_c is $-2g_c$, and the growth rate of wages w_c and the interest rate r_c is 0, where g_c is the growth rate of aggregate productivity, $c \in \{H, F\}$.*

Proof The proof is written in two steps from Home's perspective. First derive expressions for aggregate output, consumption, and prices, and then compute the aggregate growth rate.

Plugging in intermediate firms' production function, we have

$$\ln(Y_{Ht}) = \int_0^1 \ln(Y_{jHt})dj = 2Q_{Ht} + \text{CON1} \tag{5.1}$$

where $\text{CON1} = \frac{\epsilon}{\epsilon-1}\int_0^1 \ln[\omega_{1jHt}{\omega^b_{1jHt}}^{\frac{1}{\epsilon}} l_{1jHt}^{\frac{\epsilon-1}{\epsilon}} + \omega_{2jHt}{\omega^b_{2jHt}}^{\frac{1}{\epsilon}} l_{2jHt}^{\frac{\epsilon-1}{\epsilon}}(\frac{q_{2jHt}}{q_{1jHt}})^{\frac{2(\epsilon-1)}{\epsilon}} + \omega_{1jFt}{\omega^b_{1jFt}}^{\frac{1}{\epsilon}}(l_{1jFt}/\tau_F)^{\frac{\epsilon-1}{\epsilon}}(\frac{q_{1jFt}}{q_{1jHt}})^{\frac{2(\epsilon-1)}{\epsilon}} + \omega_{2jFt}{\omega^b_{2jFt}}^{\frac{1}{\epsilon}}(l_{2jFt}/\tau_F)^{\frac{\epsilon-1}{\epsilon}}(\frac{q_{2jFt}}{q_{1jHt}})^{\frac{2(\epsilon-1)}{\epsilon}}]dj$. We also have

$$\ln(P_{Ht}) = \int_0^1 \ln(P_{jHt})dj = -2Q_{Ht} + \text{CON2} \tag{5.2}$$

where $\text{CON2} = \frac{1}{1-\epsilon}\int_0^1 \ln(\omega_{1jHt}\omega^b_{1jHt}(mu_{1jHt}w_{Ht})^{1-\epsilon} + \omega_{2jHt}\omega^b_{2jHt}(mu_{2jHt}w_{Ht})^{1-\epsilon}(\frac{q_{2jHt}}{q_{1jHt}})^{2(\epsilon-1)} + \omega_{1jFt}\omega^b_{1jFt}(mu_{1jFt}w_{Ft}\tau_F)^{1-\epsilon}(\frac{q_{1jFt}}{q_{1jHt}})^{2(\epsilon-1)} + \omega_{2jFt}\omega^b_{2jFt}(mu_{2jFt}w_{Ft}\tau_F)^{1-\epsilon}(\frac{q_{2jFt}}{q_{1jHt}})^{2(\epsilon-1)})dj$.

Since in the BGP equilibrium the distribution of firms, labor demand, markup, and wage rate are invariant across technology gaps, the terms CON1 and CON2 are constant. Therefore, the growth rate of Y_{Ht} and P_{Ht} depends on Q_{Ht}. Differentiating equations (5.1) and (5.2) with respect to time yields $(\ln(Y_{Ht}))'_t = \frac{\dot{Y}_{Ht}}{Y_{Ht}} = 2\dot{Q}_{Ht} \equiv 2g_{Ht}$, $(\ln(P_{Ht}))'_t = \frac{\dot{P}_{Ht}}{P_{Ht}} = -2\dot{Q}_{Ht} \equiv -2g_{Ht}$. From the final goods market clearing condition, it is straightforward to show that $\frac{C_{Ht+\Delta t}-C_{Ht}}{C_{Ht}} = \frac{Y_{Ht+\Delta t}(1-\frac{R_{Ht+\Delta t}}{Y_{Ht+\Delta t}}) - Y_{Ht}(1-\frac{R_{Ht}}{Y_{Ht}})}{Y_{Ht}(1-\frac{R_{Ht}}{Y_{Ht}})}$. Since $\frac{R_{Ht}}{Y_{Ht}}$ is stationary along the BGP, $\frac{\dot{C}_{Ht}}{C_{Ht}} = \frac{\dot{Y}_{Ht}}{Y_{Ht}}$. The equilibrium conditions also directly imply that growth rate of wages w_{Ht} and the interest rate r_{Ht} are 0 along the BGP. Foreign is analogous.□

Lemma A.1. *Intermediate goods firms' market shares (s_{ijHt}, s^*_{ijHt}, s_{ijFt}, and s^*_{ijFt}) and markups (mu_{ijHt}, mu^*_{ijHt}, mu_{ijFt}, and mu^*_{ijFt}) are functions of the technology gaps m_{Gt}, m_{ct}, wages w_{ct}, and parameters (τ_c, etc), where $i \in \{1, 2\}$, $j \in [0, 1]$, and $c \in \{H, F\}$.*

Proof Let i and i' denote the two firms in industry j from each country. We have intermediate goods prices $p_{ijHt} = \frac{\varepsilon_{ijHt}}{\varepsilon_{ijHt}-1}\frac{w_{Ht}}{q_{ijHt}} = \frac{\epsilon-(\epsilon-1)s_{ijHt}}{\epsilon-(\epsilon-1)s_{ijHt}-1}\frac{w_{Ht}}{q_{ijHt}} \equiv mu_{ijHt}\frac{w_{Ht}}{q_{ijHt}}$. Using the demand function for y_{ijct}, we have s_{ijHt} as a function of relative prices and relative productivity:

$$s_{ijHt} = \left(1 + \frac{\omega_{i'jHt}\omega^b_{i'jHt}}{\omega_{ijHt}\omega^b_{ijHt}}(\frac{q_{i'jHt}}{q_{ijHt}})^{\epsilon-1}(\frac{p_{i'jHt}}{p_{ijHt}})^{1-\epsilon} + \frac{\omega_{ijFt}\omega^b_{ijFt}}{\omega_{ijHt}\omega^b_{ijHt}}(\frac{q_{ijFt}}{q_{ijHt}})^{\epsilon-1}(\frac{\tau_F p_{ijFt}}{p_{ijHt}})^{1-\epsilon} + \frac{\omega_{i'jFt}\omega^b_{i'jFt}}{\omega_{ijHt}\omega^b_{ijHt}}(\frac{q_{i'jFt}}{q_{ijHt}})^{\epsilon-1}(\frac{\tau_F p_{i'jFt}}{p_{ijHt}})^{1-\epsilon}\right)^{-1}. \tag{5.3}$$

The expressions for s^*_{ijHt}, s_{ijFt}, and s^*_{ijFt} can be analogously given. It is straightforward to see that the relative price is a function of market share, relative wage, and relative productivity. Relative productivity can be written as a function of the technology gaps m_G and m_c, $c \in \{H, F\}$. Given exogenous parameters ω_{ijct}, ω^b_{ijct}, τ_c, and ϵ and wages w_{ct}, there is a mapping from technology gaps to market shares. Since markup is a function of market share, a direct implication is that markup also depends strictly on the technology gaps. □

Lemma A.2. *Intermediate goods firms' optimal profits (π_{ijHt}, π^*_{ijHt}, π_{ijFt}, and π^*_{ijFt}) and sales py_{ijHt}, py^*_{ijHt}, py_{ijFt}, and py^*_{ijFt}) are functions of the technology gaps m_{Gt} and m_{ct}, wages w_{ct}, and aggregate revenue $P_{ct}Y_{ct}$, where $i \in \{1, 2\}$, $j \in [0, 1]$, and $c \in \{H, F\}$.*

Proof I prove from Home country's perspective. In the Home market, optimal profits can be written as $\pi_{ijHt} = \frac{1}{\omega_{ijHt}}[(1 - \frac{1}{mu_{ijHt}})s_{ijHt}]P_{Ht}Y_{Ht}$, where $mu_{ijHt} \equiv \frac{\epsilon-(\epsilon-1)s_{ijHt}}{\epsilon-(\epsilon-1)s_{ijHt}-1}$. The optimal profits in Foreign market can be similarly derived. So profits are a function of s_{ijct}, s^*_{ijct}, $P_{ct}Y_{ct}$, and w_{ct}. From Lemma A.1, we know market shares are a function of m_{Gt}, m_{ct} and w_{ct}. So profits are a function of m_{Gt}, m_{ct}, $P_{ct}Y_{ct}$ and w_{ct}. For future convenience, define $\Pi_{ijHt}(m_H, m_F, m_G) \equiv [(1 - \frac{1}{mu_{ijHt}})s_{ijHt}] + [(1 - \frac{1}{mu^*_{ijHt}})s^*_{ijHt}]\frac{P_{Ft}Y_{Ft}}{P_{Ht}Y_{Ht}}$ such that the total profit of the leader (mass adjusted) is $\Pi_{ijHt}(m_H, m_F, m_G)P_{Ht}Y_{Ht}$. Analogously, the mass-adjusted sales of Home firms are $(s_{ijHt} + s^*_{ijHt}\frac{P_{Ft}Y_{Ft}}{P_{Ht}Y_{Ht}})P_{Ht}Y_{Ht}$. Similar definitions can be given for Foreign. Note that the subscript j can be omitted since m_H, m_F, and m_G are sufficient to describe the industry. □

Lemma A.3. *Larger firms' markups and production profits respond more to changes in their market share, i.e., a firm's markup elasticity with respect to its market share and production profit elasticity with respect to its market share increase in its market share.*

Proof $-\frac{\partial \ln(\varepsilon_{ijct})}{\partial \ln(s_{ijct})} = \frac{s_{ijct}(\epsilon-1)}{\epsilon - s_{ijct}(\epsilon-1)} \geq 0$, where ε_{ijct} is the demand elasticity governing firm markup, s_{ijct} is the market share in the domestic or foreign market, and ϵ is the elasticity of substitution. $\frac{\partial \ln(mu_{ijct})}{\partial \ln(\varepsilon_{ijct})} = \frac{1}{1-\varepsilon_{ijct}} < 0$. Therefore, firm markup elasticity with respect to the market share is increasing in its market share is immediate. Furthermore, $\frac{\partial \ln((1-\frac{1}{mu_{ijct}})s_{ijct})}{\partial \ln(s_{ijct})} = \frac{\epsilon}{\epsilon-(\epsilon-1)s_{ijct}} > 0$. Given that firm production profit π_{ijct} in the domestic or foreign market is increasing in $(1 - \frac{1}{mu_{ijct}})s_{ijct}$ as proved above, firm production profit elasticity with respect to the market share is increasing in its market share is immediate. □

Proof of Proposition 2.

The proof is written in three steps from Home's perspective.First, define three relative prices. $\rho_1(m_H, m_F, m_G) \equiv \frac{p_{2jHt}}{p_{1jHt}}$, $\rho_2(m_H, m_F, m_G) \equiv \frac{\tau_F p_{1jFt}}{p_{1jHt}}$, $\rho_3(m_H, m_F, m_G) \equiv \frac{\tau_F p_{2jFt}}{p_{1jHt}}$. Second, write down market share, markup and profit as a function of relative prices. From Lemma A.1, we have

$s_{ijct} \equiv \frac{1}{1+B_{ijct}}$, $mu_{ijct} = \frac{1+\epsilon B_{ijct}}{(\epsilon-1)B_{ijct}}$, $\pi_{ijct} = \frac{1}{1+\epsilon B_{ijct}} \frac{P_{Ht}Y_{Ht}}{\omega_{ijct}}$, where
$B_{1jHt} = \frac{\omega_{2jHt}\omega^b_{2jHt}}{\omega_{1jHt}\omega^b_{1jHt}}(\lambda^{-m_H})^{\epsilon-1}\rho_1^{1-\epsilon} + \frac{\omega_{1jFt}\omega^b_{1jFt}}{\omega_{1jHt}\omega^b_{1jHt}}(\lambda^{-m_G})^{\epsilon-1}\rho_2^{1-\epsilon} + \frac{\omega_{2jFt}\omega^b_{2jFt}}{\omega_{1jHt}\omega^b_{1jHt}}(\lambda^{-(m_F+m_G)})^{\epsilon-1}\rho_3^{1-\epsilon}$;
$B_{2jHt} \equiv \frac{\omega_{1jHt}\omega^b_{1jHt}}{\omega_{2jHt}\omega^b_{2jHt}}(\lambda^{m_H})^{\epsilon-1}\rho_1^{\epsilon-1} + \frac{\omega_{1jFt}\omega^b_{1jFt}}{\omega_{2jHt}\omega^b_{2jHt}}(\lambda^{m_H-m_G})^{\epsilon-1}(\rho_2\rho_1^{-1})^{1-\epsilon} + \frac{\omega_{2jFt}\omega^b_{2jFt}}{\omega_{2jHt}\omega^b_{2jHt}}(\lambda^{m_H-(m_F+m_G)})^{\epsilon-1}(\rho_3\rho_1^{-1})^{1-\epsilon}$;
$B_{1jFt} \equiv \frac{\omega_{1jHt}\omega^b_{1jHt}}{\omega_{1jFt}\omega^b_{1jFt}}(\lambda^{m_G})^{\epsilon-1}\rho_2^{\epsilon-1} + \frac{\omega_{2jHt}\omega^b_{2jHt}}{\omega_{1jFt}\omega^b_{1jFt}}(\lambda^{m_G-m_H})^{\epsilon-1}(\rho_1\rho_2^{-1})^{1-\epsilon} + \frac{\omega_{2jFt}\omega^b_{2jFt}}{\omega_{1jFt}\omega^b_{1jFt}}(\lambda^{-m_F})^{\epsilon-1}(\rho_3\rho_2^{-1})^{1-\epsilon}$;
$B_{2jFt} \equiv \frac{\omega_{1jHt}\omega^b_{1jHt}}{\omega_{2jFt}\omega^b_{2jFt}}(\lambda^{m_G+m_F})^{\epsilon-1}\rho_3^{\epsilon-1} + \frac{\omega_{2jHt}\omega^b_{2jHt}}{\omega_{2jFt}\omega^b_{2jFt}}(\lambda^{m_F-m_G-m_H})^{\epsilon-1}(\rho_1\rho_3^{-1})^{1-\epsilon} + \frac{\omega_{1jFt}\omega^b_{1jFt}}{\omega_{2jFt}\omega^b_{2jFt}}(\lambda^{m_F})^{\epsilon-1}(\rho_2\rho_3^{-1})^{1-\epsilon}$.
It is immediate to prove that a firm's markup and profit increase in its market share. Third, solve for relative prices as a function of technology gaps: $\rho_1 = \frac{1+\epsilon B_{2jHt}}{1+\epsilon B_{1jHt}}\frac{B_{1jHt}}{B_{2jHt}}\lambda^{m_H}$; $\rho_2 = \frac{1+\epsilon B_{1jFt}}{1+\epsilon B_{1jHt}}\frac{B_{1jHt}}{B_{1jFt}}\lambda^{m_G}\frac{\tau_F w_{Ft}}{w_{Ht}}$; $\rho_3 = \frac{1+\epsilon B_{2jFt}}{1+\epsilon B_{1jHt}}\frac{B_{1jHt}}{B_{2jFt}}\lambda^{m_G+m_F}\frac{\tau_F w_{Ft}}{w_{Ht}}$. These three equations jointly pin down the three relative prices. Algebra yields $\lim_{m_H\to\infty}\rho_1 = \infty$, $\lim_{m_G\to\infty}\rho_2 = \infty$, $\lim_{m_G\to\infty}\rho_3 = \infty$. Therefore, for large enough m_H, π_{1jHt} is bounded given any finite m_F and m_G. It directly follows that π_{1jHt} is concave as $m_H \to \infty$. Furthermore, π_{1jHt} is weakly-increasing in m_H. For large enough m_G, π_{ijHt} is bounded given any finite m_H and m_F. It directly follows that π_{ijHt} is concave as $m_G \to \infty$. Moreover, π_{ijHt} is weakly-increasing in m_G. On the other hand, π_{2jHt} is weakly-decreasing and convex in m_H and π_{ijFt} is weakly-decreasing and convex in m_G, s_{ijct} is increasing in w_{Ft} and τ_F, which are directly from algebraic derivation. The Foreign proof is similar.

Proof of Proposition 3.

Lemma A.2 directly implies that a Home firm's scaled production profits only depend on the firm's market share in domestic and global markets, and relative aggregate expenditure $\frac{P_F Y_F}{P_H Y_H}$. The market shares are determined by trade cost τ and general equilibrium effects. The general equilibrium effects incorporate relative wages $\frac{w_F}{w_H}$ ($w_H \equiv 1$), and relative aggregate expenditure.

Proof of Proposition 4.

From Lemma A.2, the production profit of the Home firm, $\Pi_{iH}(m)P_H Y_H$, is a product of two components: the scaled production profit $\Pi_{iH}(m)$ and the domestic economy size $P_H Y_H$. Given technology gap $\boldsymbol{m}$, the change in scaled production profits due to change in market environment, e.g., change in international knowledge diffusion ι, is:

$$\begin{aligned}\Pi'_{iH}(\boldsymbol{m}) - \Pi_{iH}(\boldsymbol{m}) &= (1 - \frac{1}{mu'_{iH}(\boldsymbol{m})})s'_{iH}(\boldsymbol{m}) - (1 - \frac{1}{mu_{iH}(\boldsymbol{m})})s_{iH}(\boldsymbol{m}) \\ &+ [(1 - \frac{1}{mu^{*\prime}_{iH}(\boldsymbol{m})})s^{*\prime}_{iH}(\boldsymbol{m}) - (1 - \frac{1}{mu^*_{iH}(\boldsymbol{m})})s^*_{iH}(\boldsymbol{m})]\frac{P'_F Y'_F}{P'_H Y'_H} \\ &+ (1 - \frac{1}{mu^*_{iH}(\boldsymbol{m})})s^*_{iH}(\boldsymbol{m})\left(\frac{P'_F Y'_F}{P'_H Y'_H} - \frac{P_F Y_F}{P_H Y_H}\right),\end{aligned} \tag{5.4}$$

where s_{iH} (mu_{iH}) and s^*_{iH} (mu^*_{iH}) denote the market share (markup) of Home firm i in the domestic and foreign markets, respectively.

Lemma A.3 directly implies that any forces increasing market shares will raise large firms' markups and production profits more than those of small firms. Conversely, forces decreasing market shares will reduce the markups and production profits of large firms more than those of small firms. Therefore, the first row in equation (5.4) implies that, given the technology gaps, the lower domestic market share of Home firms will reduce the domestic profits of leaders more than that of domestic followers. The second row in equation (5.4) implies that the higher foreign market share of Home firms will increase the foreign profits of Home leaders more than those of Home followers. The third row in equation (5.4) implies that a higher foreign demand $\frac{P_F Y_F}{P_H Y_H}$ will increase the foreign profits of Home leaders more than those of Home followers.

Proof of Proposition 5.

We consider a simplified version of the model economy with two symmetric countries that abstracts from trad costs ($\tau_c = 1, c \in \{H, F\}$, $w_H = w_F$, $P_F Y_F = P_H Y_H$), sets the maximum global technology gap to one ($\bar{m}_G = 1$), assumes there is only one firm from each country per industry $j \in [0, 1]$ making production and innovation decisions, but there is a competitive fringe in each country per industry that occupies a certain market share (for any reason). Therefore, firms make decisions taking into account the market share of the competitive fringe. This is a simple way, without loss of generality, to demonstrate the effect of domestic competition on firms' competition with foreign competitors. In particular, a larger market share of the competitive fringe indicates that firms have fewer extra profits from additional innovation. This aligns with the full model with a significant technological gap among domestic firms.[50] The numerical results in a full model, as shown in the main text, demonstrate that endogenizing the competitive fringe by assuming they make decisions to compete with domestic and foreign competitors leads to similar results.

To simplify notations, define $\alpha \equiv \frac{\epsilon-1}{\epsilon}$, $0 < \alpha < 1$. Define the relative price between Home firm and Home competitive fringe as $\frac{p_H(m_G)}{p_C(m_G)}$. Without loss of generality, assume that $0 < \frac{p_H(m_G)}{p_C(m_G)} \leq 1$, i.e., Home competitive fringe is less productive and has lower market share than the Home firm. A smaller $\frac{p_H(m_G)}{p_C(m_G)}$ implies that Home competitive fringe is much less productive than Home firm and accounts for smaller market share. Define the marginal cost of production between Home firm and Foreign firm as $\frac{c_H}{c_F} > 0$. The marginal cost of production could differ across firms due to the productivity difference across firms. As all industries are symmetric, we only consider firms' static production problems within one industry. Therefore, $\frac{p_H(m_G)}{p_C(m_G)}$ is simplified as $\frac{p_H}{p_C}$.

In Home market, the market share of Home firm and Foreign firm in an industry is defined as s_H, s_F, respectively. Total market share of two firms in Home market is $T = s_H + s_F$, where $0 < T \leq 1$. The optimal production profits of Home firm and Foreign firm is represented by $\Pi_H(m_G)PY$ and $\Pi_F(m_G)PY$, where $\Pi_H(m_G)$ and $\Pi_F(m_G)$ are named as the scaled production profits. Foreign market notations are symmetrically given with an asterisk: s^*_H, s^*_F, T^*, Π^*_H, Π^*_F. The global production profits are represented by $\Pi^T_H = \Pi_H + \Pi^*_H$ and $\Pi^T_F = \Pi_F + \Pi^*_F$. Given that two countries are symmetric and $m_G \in \{-1, 0, 1\}$, $\Pi^T_H(m_G)$ and $\Pi^T_F(m_G)$ essentially only have three values: π_{-1}, π_0, π_1, that is, $\Pi^T_H(0) = \Pi^T_F(0) \equiv \pi_0$, $\Pi^T_H(-1) = \Pi^T_F(1) \equiv \pi_{-1}$, and $\Pi^T_H(1) = \Pi^T_F(-1) \equiv \pi_1$.

Without loss of generality, define the innovation cost as $\frac{x^2_{m_G}}{2} P_c Y_c$, where x_{m_G} denotes Poisson arrival rate, $c \in \{H, F\}$. Next, divide the value of firms V_{m_G} by $P_c Y_c$ to have scaled value v_{m_G}. The value function of the Home firm becomes

$$\rho v_1 = \max_{x_1} \{\pi_1 - \frac{x_1^2}{2} + x_1(v_1 - v_1) + (x_{-1} + \iota)(v_0 - v_1)\}, \tag{5.5}$$

$$\rho v_{-1} = \max_{x_{-1}} \{\pi_{-1} - \frac{x_{-1}^2}{2} + x_1(v_{-1} - v_{-1}) + (x_{-1} + \iota)(v_0 - v_{-1})\}, \tag{5.6}$$

[50] Alternatively, this suggests that a firm's value primarily has a concave relationship with the domestic technology gap.

$$\rho v_0 = \max_{x_0}\{\pi_0 - \frac{x_0^2}{2} + x_0(v_1 - v_0) + (x_0)(v_{-1} - v_0)\}. \tag{5.7}$$

The optimal innovation decision rule is

$$x_1 = 0,$$
$$x_0 = v_1 - v_0,$$
$$x_{-1} = v_0 - v_{-1}.$$

Define μ as the share of industries with $m_G \neq 0$, then $(1-\mu)$ is the share of neck-and-neck industries. The law of motion for μ is $\dot{\mu} = -\mu(x_{-1} + \iota) + (1-\mu)2x_0$. In a BGP, $\dot{\mu} = 0$ leads to that

$$\mu = \frac{2x_0}{2x_0 + x_{-1} + \iota}. \tag{5.8}$$

The aggregate growth rate is

$$g = 2x_0(1-\mu)\ln(\lambda). \tag{5.9}$$

The proof for (a) is written in three steps.

Step 1. Prove that $\frac{\partial s_H}{\partial \frac{p_H}{p_C}} < 0, \forall \frac{c_H}{c_F}$. From Lemma A.1, it is direct that

$$\frac{p_H}{p_F} = \frac{c_H}{c_F}\frac{1-\alpha s_H}{1-s_H}\frac{s_H - T + 1}{\alpha s_H - \alpha T + 1}, \tag{5.10}$$

$$s_H = \left(1 + (\frac{p_H}{p_F})^{\frac{\alpha}{1-\alpha}} + (\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}\right)^{-1}, \tag{5.11}$$

and

$$s_F = \left(1 + (\frac{p_H}{p_F})^{\frac{\alpha}{\alpha-1}} + (\frac{p_H}{p_F})^{\frac{\alpha}{\alpha-1}}(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}\right)^{-1}. \tag{5.12}$$

Plugging (5.10) into (5.11), Home firm market share s_H in Home market can be expressed as a function of total market share in Home market T and relative price between Home firm and competitive fringe $\frac{p_H}{p_C}$:

$$s_H = \left(1 + \left(\frac{c_H}{c_F}\frac{1-\alpha s_H}{1-s_H}\frac{s_H - T + 1}{\alpha s_H - \alpha T + 1}\right)^{\frac{\alpha}{1-\alpha}} + (\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}\right)^{-1}; \tag{5.13}$$

total market share T can be expressed as a function of Home firm market share s_H and relative price between Home firm and competitive fringe $\frac{p_H}{p_C}$:

$$T = 1 - \frac{(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}}{1 + (\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}} + \left(\frac{c_H}{c_F}\frac{1-\alpha s_H}{1-s_H}\frac{s_H-T+1}{\alpha s_H - \alpha T + 1}\right)^{\frac{\alpha}{1-\alpha}}}. \tag{5.14}$$

Plugging (5.13) into (5.14) and rearranging, we have

$$T = 1 - s_H(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}. \tag{5.15}$$

Therefore, the value of s_H only depends on α, $\frac{c_H}{c_F}$, and $\frac{p_H}{p_C}$. It is direct that higher $\frac{p_H}{p_C}$ leads to lower T, as competitive fringe accounts for larger market share. As $\frac{p_H}{p_C} \to 0$, $T \to 1$. In this limiting case, the competitive fringe is so unproductive relative to the Home firm, such that it accounts for zero market share and does not affect firms' decisions. On the other hand, Given $s_H \in [0, T]$ and equation (5.15), we have $0 \le s_H \le \frac{1}{1+(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}} \le 1$.

Rearranging (5.13) and taking the logarithm,

$$\begin{aligned}\frac{1-\alpha}{\alpha}\log(s_H) + \log(\frac{c_H}{c_F}) + \log(1-\alpha s_H) + \log(1-(T-s_H)) - \log(1-s_H) \\ - \log(1-\alpha(T-s_H)) - \frac{1-\alpha}{\alpha}\log(1-s_H-s_H(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}) = 0.\end{aligned} \tag{5.16}$$

Plugging (5.15) into (5.16), we have

$$\begin{aligned}(1-\alpha)\log(s_H) + \alpha\log(\frac{c_H}{c_F}) + \alpha\log(1-\alpha s_H) - \alpha\log(1-s_H) + \alpha\log(s_H(1+(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}})) \\ -\alpha\log(1-\alpha(1-s_H(1+(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}))) - (1-\alpha)\log(1-s_H(1+(\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}})) = 0.\end{aligned} \tag{5.17}$$

Define the left-hand side of equation (5.17) as $F(s_H)$, it is direct to see that $F(s_H)$ is a function of s_H, α, $\frac{c_H}{c_F}$, and $\frac{p_H}{p_C}$. Taking the derivative of $F(s_H)$ with respect to s_H, we have

$$F'(s_H) = \frac{1}{s_H} - \frac{\alpha^2}{1-\alpha s_H} + \frac{\alpha}{1-s_H} - \frac{\alpha^2 CON}{1-\alpha(1-s_H CON)} + \frac{(1-\alpha)CON}{1-s_H CON},$$

where $CON \equiv 1 + (\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}} \ge 1$. Define $G(a,s) = \frac{a^2}{1-as} + \frac{CONa^2}{1-a(1-sCON)} - \frac{(1-a)CON}{1-sCON} - \frac{a-1}{1-s}$, then we have

$$F'(s_H) = G(1, s_H) - G(\alpha, s_H). \tag{5.18}$$

Taking the derivative of $G(a,s)$ with respect to a, $\frac{\partial G(a,s)}{\partial a} = \frac{a(2-sa)}{(1-as)^2} + CON\frac{a((2-a)+asCON)}{(1-a(1-sCON))^2} + \frac{CON-1}{(1-s)(1-sCON)}$. It is easy to show that $\frac{\partial G(a,s)}{\partial a} > 0$ for $\forall s \in [0,1]$ and $\forall a \in (0,1)$. Recall $F'(s_H) = G(1,s_H) - G(\alpha, s_H)$, $F'(s_H) > 0$ for $\forall s \in [0,1]$. From equations (5.17) and (5.18), and the implicit function theorem that the value of s_H is given by a function $s(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C})$, it is easy to see that s_H is strictly decreasing in $\frac{c_H}{c_F}$ given a level of $\frac{p_H}{p_C}$; s_H is strictly decreasing in $\frac{p_H}{p_C}$ given a level of $\frac{c_H}{c_B}$.

Step 2. Prove that $\frac{\partial[(\pi_1-\pi_0)-(\pi_0-\pi_{-1})]}{\partial\frac{p_H}{p_C}} < 0$. By symmetry, $s_F = s(\alpha, \frac{c_F}{c_H}, \frac{p_F}{p_C})$. Since $s_H + s_F = T$,

$$s(1, \alpha, \frac{p_H}{p_C}) = \frac{T}{2}. \tag{5.19}$$

From equation (3.7), the optimal profit in Home market in this simplified model becomes

$$\Pi(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C}) = \frac{(1-\alpha)s(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C})}{1-\alpha s(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C})}. \tag{5.20}$$

Suppose without loss of generality that $0 < \frac{c_H}{c_F} < 1$ so that $s_H > \frac{T}{2}$. From equations (5.19) and (5.20),

$$\Pi(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C}) + \Pi(\alpha, \frac{c_F}{c_H}, \frac{p_F}{p_C}) - 2\Pi(\alpha, 1, \frac{p_H}{p_C}) \equiv (1-\alpha)[H(s(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C})) - H(\frac{T}{2})], \tag{5.21}$$

where $H(s) \equiv \frac{s}{1-\alpha s} + \frac{T-s}{1-\alpha(T-s)}$, and s is short for $s(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C})$. It is direct that $\frac{\partial H}{\partial s} > 0$ when $s > \frac{T}{2}$.

So $\Pi(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C}) + \Pi(\alpha, \frac{c_F}{c_H}, \frac{p_F}{p_C}) - 2\Pi(\alpha, 1, \frac{p_H}{p_C}) > 0$.[51]

Next, prove that $\Pi(\alpha, \frac{c_H}{c_F}, \frac{p_H}{p_C}) + \Pi(\alpha, \frac{c_F}{c_H}, \frac{p_F}{p_C}) - 2\Pi(\alpha, 1, \frac{p_H}{p_C})$ is decreasing in $\frac{p_H}{p_C}$. From equations (5.17) and (5.12), it is direct that $\frac{\partial s_H}{\partial (\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}} < 0$. Given that $\frac{\partial H}{\partial s} > 0$, it is direct that $\frac{\partial H}{\partial (\frac{p_H}{p_C})^{\frac{\alpha}{1-\alpha}}} < 0$ when $s > \frac{T}{2}$. Foreign market results are symmetrically given. Therefore, $\frac{\partial[(\pi_1-\pi_0)-(\pi_0-\pi_{-1})]}{\partial \frac{p_H}{p_C}} < 0$. It is direct that $[(\pi_1 - \pi_0) - (\pi_0 - \pi_{-1})]$ is strictly decreasing in the market share of competitive fringe.

Step 3. Prove $\frac{\partial[x_0-x_{-1}]}{\partial \frac{p_H}{p_C}} < 0$. Rearranging (5.5) and (5.7), we have

$$(\rho + x_{-1} + \iota + x_0)(v_1 - v_0) = \pi_1 - \pi_0 + \frac{x_0^2}{2} + x_0(v_0 - v_{-1}), \tag{5.22}$$

which implies

$$x_0 = -(\rho + \iota) + \left((\rho + \iota)^2 + 2(\pi_1 - \pi_0)\right)^{\frac{1}{2}}. \tag{5.23}$$

It is direct that $\frac{\partial x_0}{\partial(\pi_1-\pi_0)} > 0$. Rearranging (5.7) and (5.6), we have

$$(\rho + x_0 + x_{-1} + \iota)(v_0 - v_{-1}) = (\pi_0 - \pi_{-1}) - \frac{x_0^2}{2} + \frac{x_{-1}^2}{2} + x_0(v_1 - v_0), \tag{5.24}$$

which implies that

$$\frac{x_{-1}^2}{2} + x_{-1}(\rho + \iota + x_0) - \frac{x_0^2}{2} - (\pi_0 - \pi_{-1}) = 0. \tag{5.25}$$

It is easy to prove $x_{-1} < x_0$ by contradiction. Suppose $x_0 \le x_{-1}$, rearranging (5.25) and (5.23) implies that $\pi_0 - \pi_{-1} \ge \pi_1 - \pi_0 + \frac{x_0^2}{2}$, which contradicts with $\pi_1 - \pi_0 > \pi_0 - \pi_{-1}$ shown in Step 2. So $x_{-1} < x_0$. From (5.25), it is direct that $x_{-1} > 0$. From (5.23), $\frac{\partial x_0}{\partial(\pi_1-\pi_0)} = \left((\rho + \iota)^2 + 2(\pi_1 - \pi_0)\right)^{\frac{1}{2}}$, which directly implies that $0 < \frac{\partial x_0}{\partial(\pi_1-\pi_0)} < 1$. From (5.25), $\frac{\partial x_{-1}}{\partial(\pi_0-\pi_{-1})} = (x_{-1} + x_0 + \iota + \rho)^{-1}$, which directly implies that $0 < \frac{\partial x_{-1}}{\partial(\pi_0-\pi_{-1})} < 1$, for $\forall 0 < x_0 \le 1$. It is easy to see that $0 < \frac{\partial x_{-1}}{\partial(\pi_0-\pi_{-1})} < \frac{\partial x_0}{\partial(\pi_1-\pi_0)} < 1$ for $\forall 0 < x_0 \le 1$. Based on Step 2 and Lemma A.3, it must be that when the increase in $\frac{p_H}{p_C}$ leads to a decrease in $[(\pi_1 - \pi_0) - (\pi_0 - \pi_{-1})]$, $(\pi_1 - \pi_0)$ decreases more than $(\pi_0 - \pi_{-1})$. Therefore, the increase in $\frac{p_H}{p_C}$ leads to a decrease in x_{-1} and x_0, and x_0 reduces more than x_{-1}. $\frac{\partial[x_0-x_{-1}]}{\partial \frac{p_H}{p_C}} < 0$ is directly obtained.

The proof for (b) is written in three steps.

Step 1. Prove that $-1 < \frac{dx_0}{d\iota} < \frac{dx_{-1}}{d\iota} < 0$. Total differentiating (5.23), $\frac{\partial x_0}{\partial \iota} = -\frac{x_0}{x_0+\rho+\iota}$, and it is easy to show that $-1 < \frac{\partial x_0}{\partial \iota} < 0$. Total differentiating (5.25), $\frac{\partial x_{-1}}{\partial \iota} = -\frac{(x_0-x_{-1})x_0}{(x_0+x_{-1}+\rho+\iota)(x_0+\rho+\iota)}$, and it is direct that $-1 < \frac{dx_0}{d\iota} < \frac{dx_{-1}}{d\iota} < 0$.

[51] In a limiting case $\frac{p_H}{p_C} \to 0$, this result is the same as the result (c) of Proposition 1 in Aghion et al. (2001), though which considers a closed-economy setup.

Step 2. Prove that $\frac{\partial \mu}{\partial \iota} < 0$. Total differentiating (5.8),

$$\frac{\partial \mu}{\partial \iota} = \frac{2\frac{\partial x_0}{\partial \iota} - \mu(1 + 2\frac{\partial x_0}{\partial \iota} + \frac{\partial x_{-1}}{\partial \iota})}{x_{-1} + \iota + 2x_0} = \frac{2x_0[-(x_0 + x_{-1} + \rho + \iota)(x_0 + x_{-1} + \iota + \rho + \iota) + x_0(x_0 - x_{-1})]}{(x_{-1} + \iota + 2x_0)^2(x_0 + \rho + \iota)(x_0 + x_{-1} + \rho + \iota)}. \tag{5.26}$$

Therefore, the sign of $\frac{\partial \mu}{\partial \iota}$ depends on the term $[-(x_0+x_{-1}+\rho+\iota)(x_0+x_{-1}+\iota+\rho+\iota)+x_0(x_0-x_{-1})]$. Given that $x_0 + x_{-1} + \rho + \iota > 0$ and $x_0 + x_{-1} + \rho + \iota > x_0 - x_{-1}$, it is easy to show that $\frac{\partial \mu}{\partial \iota} < 0$.

Step 3. Prove that $\frac{\partial g}{\partial \iota} < 0$ as $\iota \to 1$. Based on (5.9),

$$\frac{\partial g}{\partial \iota} = -\frac{\left(\frac{2x_0^3(\rho+\iota+2x_0)}{x_0+x_{-1}+\rho+\iota} - (2x_0^2 + 2\rho x_0)(x_0 + x_{-1} + \rho + \iota) + x_0(x_{-1} + \rho + \iota + x_0)^2 + (\rho^2 x_0 - 2\iota x_0^2 - 3x_0^3)\right)}{(2x_0 + x_{-1} + \iota)^2(x_0 + \rho + \iota)(2\ln(\lambda))^{-1}}, \tag{5.27}$$

where the numerator can be rewritten as

$$\begin{aligned} &\frac{2x_0^3(2x_0 + \rho + \iota)}{\sqrt{(\rho + \iota + x_0)^2 + 2(\frac{x_0^2}{2} + \pi_0 - \pi_{-1})}} - (2x_0^2 + 2\rho x_0)\sqrt{(\rho + \iota + x_0)^2 + 2(\frac{x_0^2}{2} + \pi_0 - \pi_{-1})} \\ &+ x_0(\rho + \iota + x_0)^2 + 2x_0(\frac{x_0^2}{2} + \pi_0 - \pi_{-1}) + (\rho^2 x_0 - 2\iota x_0^2 - 3x_0^3), \end{aligned} \tag{5.28}$$

given that $x_0 + x_{-1} + \rho + \iota = \sqrt{(\rho + \iota + x_0)^2 + 2(\frac{x_0^2}{2} + \pi_0 - \pi_{-1})}$. According to (5.23) and (5.25), it is direct that $\frac{\partial g}{\partial \iota}$ is a function of $\rho, \iota, \pi_1 - \pi_0$ and $\pi_0 - \pi_{-1}$.

Numerically, it is easy to show that there is a cutoff $\bar{\iota}$ such that $\frac{\partial g}{\partial \iota} \le 0$ if $\iota > \bar{\iota}$ and $\frac{\partial g}{\partial \iota} > 0$ if $\iota < \bar{\iota}$. As $\frac{\partial \mu}{\partial \iota} < 0$ and μ measures the fraction of unleveled industries, a higher ι is associated with more neck-and-neck industries, and hence lower global technological advantage of Home. Therefore, lower global technological advantage, more likely to have $\frac{\partial g}{\partial \iota} \le 0$. Furthermore, $\frac{\partial \bar{\iota}}{\partial \frac{p_H}{p_C}} \le 0$. That is, more market share of competitive fringe, more likely to have $\frac{\partial g}{\partial \iota} \le 0$.

Analytically, we show under a limiting case that $\iota \to 1$ and $\rho \to 0$, $\frac{\partial g}{\partial \iota} < 0$. To show $\frac{\partial g}{\partial \iota} < 0$, it is sufficient to show that (5.28) > 0. (5.28) in this limiting case converges

$$\tilde{L} = \frac{4}{D}x_0^4 + (D^2 - D)x_0 + (\frac{2}{D} - 3)x_0^3 - (2D + 2)x_0^2 - 2D, \tag{5.29}$$

where $D \equiv \sqrt{1 + x_0^2 + 2(\pi_0 - \pi_{-1}) + 2(\pi_1 - \pi_0)}$. Note that $D^2 > D > 1$. As $x_0 = -1 + (1 + 2(\pi_1 - \pi_0))^{\frac{1}{2}}$, D can be further simplified as $D = \sqrt{3 + 4(\pi_1 - \pi_0) + 2(\pi_0 - \pi_{-1}) - 2(1 + 2(\pi_1 - \pi_0))^{\frac{1}{2}}}$. Given (5.20), it is easy to see that $0 \le \pi_{-1} < \pi_0 = \frac{2T(1-\alpha)}{2-\alpha T} < \pi_1 \le 2\frac{(1-\alpha)T}{1-\alpha T}$. When $\frac{c_H}{c_F}$ is sufficiently high, $\pi_1 = 2\frac{(1-\alpha)T}{1-\alpha T}$ and $\pi_{-1} = 0$. Therefore, $0 < \pi_1 - \pi_0 \le \frac{2T(1-\alpha)}{(1-\alpha T)(2-\alpha T)}$, $0 < \pi_0 - \pi_{-1} \le \frac{2T(1-\alpha)}{2-\alpha T}$. After tedious algebra, we can show that there exists $\bar{T}$ and $\bar{\alpha}$ such that $\tilde{L} > 0$ when $T < \bar{T}$ and $\alpha < \bar{\alpha}$. Furthermore, $\partial|\frac{\partial g}{\partial \iota}|/\partial \bar{T} < 0$ when $T < \bar{T}$ and $\alpha < \bar{\alpha}$. That is, when there is a higher market share of competitive fringe, higher ι leads to a more significant negative impact on growth.

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Online Appendix for "Uneven Firm Growth in a Globalized World"

A Baseline Model Details

A.1 Evolution of Technology Gap Distribution

The laws of motion that summarize this endogenous process can be written as follows:

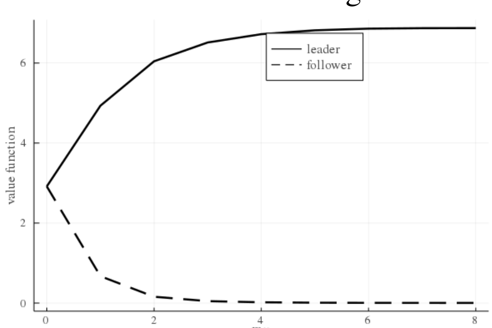
$$\begin{aligned}\dot{\mu}_t(\boldsymbol{m}) &= -\left(x_{1H}(\boldsymbol{m}) + x_{2H}(\boldsymbol{m}) + x_{1F}(\boldsymbol{m}) + x_{2F}(\boldsymbol{m}) + \kappa \cdot \mathbb{1}_{m_H>0} + \kappa \cdot \mathbb{1}_{m_F>0} + 2\iota \cdot \mathbb{1}_{m_G \neq 0}\right) \cdot \mu_t(\boldsymbol{m}) \\ &+ \sum_i \sum_{n_H} \sum_{n_G} \left(x_{iH}(n_H, m_F, n_G) + \kappa \cdot \mathbb{1}_{n_H>0} + 2\iota \cdot \mathbb{1}_{n_G<0}\right) \cdot F_{iH}(n_H, n_G, m_H, m_G) \cdot \mu_t(n_H, m_F, n_G) \\ &+ \sum_i \sum_{n_F} \sum_{n_G} \left(x_{iF}(m_H, n_F, n_G) + \kappa \cdot \mathbb{1}_{n_F>0} + 2\iota \cdot \mathbb{1}_{n_G>0}\right) \cdot F_{iF}(n_F, n_G, m_F, m_G) \cdot \mu_t(m_H, n_F, n_G),\end{aligned} \tag{A.1}$$

where $\mathbb{1}_{n_G<0}$ is an indicator function that equals one if $n_G < 0$. The first line on the right-hand side in equation (A.1) characterizes the decrease in $\mu_t(\boldsymbol{m})$ due to firms in state $\boldsymbol{m}$ innovating or receiving knowledge spillovers. The second and third lines characterize the increase in $\mu_t(\boldsymbol{m})$ due to increases in the productivity of Home leaders, Home followers, Foreign leaders, and Foreign followers in other states that transition to state $\boldsymbol{m}$. The technology gap distribution in the steady state requires that the mass of industries entering and leaving each state is equal over time.

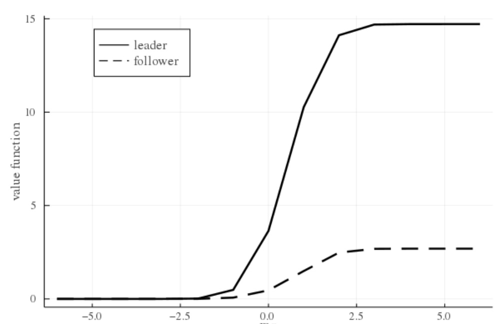
A.2 Numerical Example of Model Mechanism

Figure A.1 plots numerical Home firms' value functions. It shows the Home leader (follower) value is increasing and eventually concave (decreasing and convex) in the domestic technology gap m_H and increasing, initially convex, and eventually concave in the global technology gap m_G. The eventual concavity of leader value functions over the domestic and global technology gaps indicates that leader innovation eventually decreases as their market share grows and they face decreasing returns to additional innovation. While the initial convexity of the value function indicates that firm innovation increases as their market share grows.

Figure A.1: Value Functions



(a) $v_{iH}(m_H, 0, 0)$

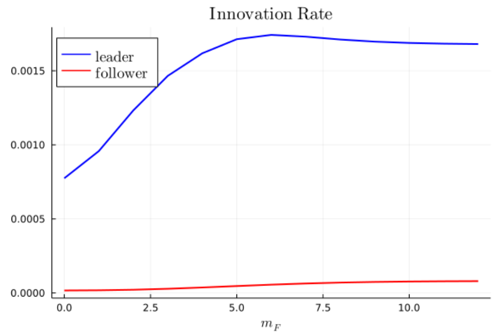


(b) $v_{iH}(1, 0, m_G)$

Notes: This figure plots numerical Home value functions in terms of the domestic technology gap m_H (given $m_F = 0$, $m_G = 0$) and global technology gap m_G (given $m_H = 1$, $m_F = 0$).

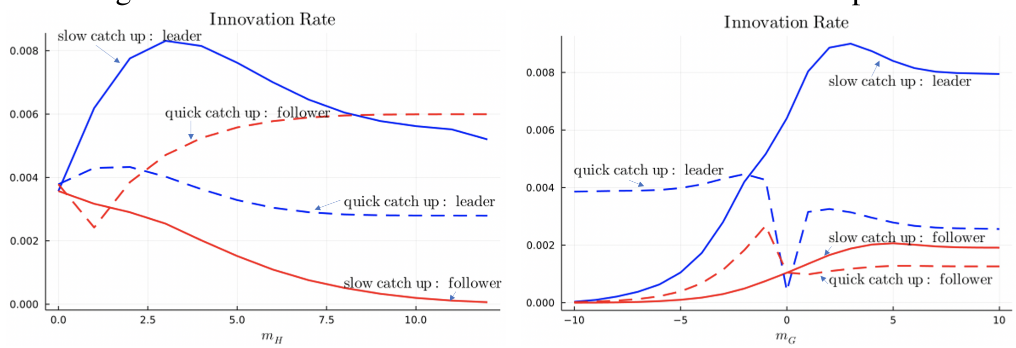
Figure A.2 plots numerical Home innovation decisions in terms of the Foreign domestic technology gap given the other two technology gaps when firms catch up to leading firms slowly. As the Foreign domestic technology gap increases, Home innovation rates first increase then decrease. This is because a larger Foreign domestic technology gap indicates larger market shares and profits for Foreign firms.[52] When Foreign market share is low, Home firms want to innovate more to escape from competition. However, when Foreign market share is high, Home firms want to innovate less because they get discouraged.

Figure A.2: Innovation Decisions Under Slow Catch-up



Notes: This figure plots numerical Home innovation decisions in terms of the Foreign domestic technology gap m_F, given the global technology gap m_G is -4 and Home's domestic technology gap m_H is 6.

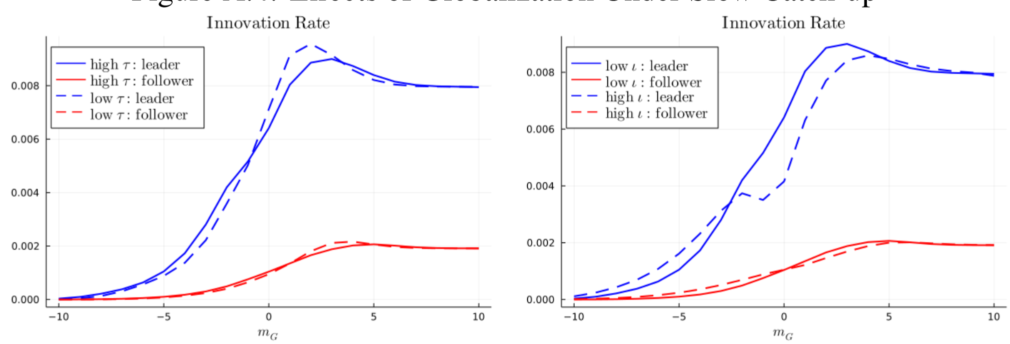
Figure A.3: Innovation Decisions Under Alternative Assumptions



(a) quick domestic catch-up ($\phi_c = 1$) (b) quick international catch-up ($\delta_c = 1$)

Notes: This figure plots numerical Home innovation decisions under the same states as in Figure 3.1 for alternative assumptions.

Figure A.4: Effects of Globalization Under Slow Catch-up



(a) market size + import competition (b) international business stealing

Notes: This figure plots numerical Home innovation decisions under the same states as in Figure 3.1 for different effects of globalization. The market size and import competition effects in panel (a) are purely driven by the change in trade cost τ and the international business stealing effect in panel (b) is solely driven by the change in international knowledge spillover ι (not relative wage and aggregate expenditure, due to the symmetric country assumption).

[52] Lemma 4.2 in Liu et al. (2022) can justify this argument. Although Lemma 4.2 was proven in a closed economy setup, the intuition for the open economy setup is the same.

A.3 Welfare Computation

The welfare of country c over horizon T at time t is $W_{ct} = \int_t^{t+T} \exp(-\rho(s-t)) \log(C_{cs}) ds$. Following the approach of Akcigit et al. (2018), I present the welfare effect of globalization (or more generally, the differences in welfare between a counterfactual and the baseline economy) in consumption equivalent terms as shown below:

$$\int_t^{t+T} \exp(-\rho(s-t)) \log(C_{cs}^{new}) ds = \int_t^{t+T} \exp(-\rho(s-t)) \log\left((1+\varsigma)C_{cs}^{base}\right) ds. \tag{A.2}$$

This equation explains that if globalization at time t generates a new consumption path C_{cs}^{new} between t and $t+T$, it leads to a ς % variation in consumption-equivalent welfare over the horizon T. In other words, it results in a ς % increase in consumption at each point in time between t and $t+T$. In my quantitative analysis, I consider the welfare change in both the transition and the new BGP as $T \to \infty$.

B Model Extensions

I show that the model mechanism and results do not hinge on the assumptions made and are robust to some modeling extensions and alternative estimations. Specifically, (i) the baseline model mechanism is strengthened by **assuming not all firms export**; (ii) introducing **endogenous entry and exit** predicts that globalization explains not only the increasing domestic concentration and lower productivity growth, but also the declining entry rate and the share of young firms in the whole economy, which are also recent secular trends in OECD countries as summarized by Akcigit and Ates (2023); (iii) introducing **endogenous firm choice between incremental and radical innovation** would strengthen the effects of globalization on rising concentration and falling productivity growth; (iv) modeling **international knowledge spillovers that endogenously vary with trade** will predict qualitatively similar but quantitatively smaller effects of globalization, given that other forces of international knowledge spillovers (e.g., FDI, migration) are shut down; (v) assuming that **backward firms are more likely to get knowledge spillovers** motivated by König et al. (2022), or that **knowledge spillovers directly close the technology gap** among firms like Akcigit and Ates (2023), the quantitative results are similar to the baseline case; (vi) if **fraction of leaders is 1 or 5 percent instead of 1 percent**, the quantitative results are similar to the baseline case, alleviating people's concern that finite number of firms fail to capture the firm size distribution and hence fail to provide valid aggregate implications. The quantitative findings under these alternative setups are in Table B.1.

B.1 Restricted Exporting

I assume leaders export while followers do not to capture how large firms are more likely to export. The recalibration results under this alternative setup suggest higher domestic concentration and slower productivity growth than baseline model. This is because the market size effect of globalization (due to larger export profits) no longer works for followers. Harsher foreign competition lowers follower domestic market shares and innovation incentives, contributing to weaker domestic competition compared to the baseline model. The lower innovation incentives induced by weaker domestic competition further lead to a smaller OECD global technological advantage. Therefore, the mechanism is strengthened by assuming not all firms export. Alternatively, I assume firms have to pay per-period fixed export costs in units of labor to have some fraction of firms exporting (target

Table B.1: Discussion of Model Assumptions and Extensions (BGP Analysis)

	(1) Restricted exporting	(2) Endogenous entry and exit	(3) Endogenous step size	(4) Int'l spillovers vary with trade	(5) State-dependent spillovers	(6) Spillovers close gaps	(7) Mass of leaders top 5%	(8) Mass of leaders top 1
Panel A. Technology gaps								
ΔDomestic gap	1.21	1.16	1.25	0.97	1.13	1.15	1.13	1.14
ΔGlobal gap	-0.86	-0.81	-0.91	-0.54	-0.81	-0.85	-0.81	-0.79
Panel B. Uneven firm growth								
ΔLeader sales premium	0.49	0.45	0.51	0.24	0.42	0.43	0.40	0.42
ΔLeader exports premium		0.81	0.86	0.39	0.79	0.81	0.77	0.80
Panel C. Aggregates								
ΔTFP growth rate,%	-0.45	-0.41	-0.49	-0.23	-0.40	-0.51	-0.39	-0.43
ΔDomestic concentration	0.08	0.07	0.09	0.04	0.06	0.07	0.07	0.07
ΔGlobal output share	-0.02	-0.01	-0.03	-0.01	-0.01	-0.01	-0.01	-0.01
ΔAggregate markup	0.11	0.14	0.12	0.09	0.14	0.12	0.13	0.14

Notes: This table presents the effect of globalization on OECD from initial to new BGP in alternative models, holding the other parameters fixed at their initial values.

30 percent to be consistent with some data evidence), making larger firms more likely to export. The results are quantitatively similar because of the relatively small increase in follower exports (in terms of absolute value) in response to globalization.[53]

B.2 Endogenous Entry and Exit

In the baseline model there is no entry and exit for simplicity. However, the data indicates entry and exit of firms matters for firm growth incentives. To this end, I assume in each period there is a potential entrant in each industry-country pair that makes innovation decisions such that with some probability the entrant can replace the follower. Potential entrants pay an innovation cost $\tilde{R}_{ct}(\boldsymbol{m}) = \frac{\tilde{\alpha}_c}{\tilde{\gamma}_c}\tilde{x}_{ct}(\boldsymbol{m})^{\tilde{\gamma}_c}$ to have a Poisson arrival rate of innovation $\tilde{x}_{ct}(\boldsymbol{m})$. Once the innovation is successful, the entrant replaces the follower and the follower exits the market with zero value. Otherwise, the entrant disappears with zero value. Note that modeling entrants which can only replace followers captures realistic firm life-cycle dynamics where entrants cannot directly become leaders, consistent with the empirical evidence (Cavenaile et al. (2019) also modeled in this way). In terms of innovation outcomes, I explain from the perspective of Home firms. Suppose Home firms are global leaders (or globally neck-and-neck), then with probability $\tilde{\phi}_H$, the entrant closes the domestic technology gap with the leader (quick domestic catch-up); with probability $1-\tilde{\phi}_H$, the entrant reduces the domestic technology gap with the leader by 1 (slow domestic catch-up). Suppose Home firms are not global leaders, then with probability $\tilde{\phi}_H$, the entrant closes the domestic technology gap with the domestic leader (quick domestic catch-up); with probability $\tilde{\delta}_H$, the entrant closes the global technology gap with the global leader (quick international catch-up); with probability $1-\tilde{\phi}_H-\tilde{\delta}_H$, the entrant reduces the domestic technology gap with the leader by 1 (slow domestic catch-up). A probability distribution function $\tilde{F}_H(m_H, m_G, m'_H, m'_G)$ summarizes entrants' innovation outcomes as follows:

$$\tilde{F}_H(m_H, m_G, m'_H, m'_G) = \begin{cases} 1-\tilde{\phi}_H & \text{if } m'_H = \max\{m_H-1, 0\}, m'_G = m_G, m_H > 0, \text{ and } m_G \geq 0, \\ \tilde{\phi}_H & \text{if } m'_H = 0, m'_G = m_G, \text{ and } m_H > 0 \\ \tilde{\delta}_H & \text{if } m'_H = \min\{|m_G|, \bar{m}_H\}, m'_G = 0, m_H > 0 \text{ and } m_G < 0, \\ 1-\tilde{\phi}_H-\tilde{\delta}_H & \text{if } m'_H = \max\{m_H-1, 0\}, m'_G = m_G, m_H > 0 \text{ and } m_G < 0, \\ 0 & \text{otherwise.} \end{cases}$$

[53] This fixed export cost will also cause industries with a comparative advantage in productivity to be more likely to export than industries without a comparative advantage. On average, the market size effect of globalization dominates and contributes to a larger profit increase for leaders than followers.

Representative consumers own firms (incumbents and potential entrants). The sum of firm value is $A_{ct} = \sum_{\boldsymbol{m}}[\sum_{i=1}^{2} V_{ict}(\boldsymbol{m}) + \tilde{V}_{ct}(\boldsymbol{m})]\mu(\boldsymbol{m})$, where V_{ict} is the incumbent value and $\tilde{V}_{ct}$ is the entrant value. The Home entrant's innovation problem is

$$\tilde{V}_{Ht}(\boldsymbol{m}) = \max_{\tilde{x}_{Ht}(\boldsymbol{m})} \{\tilde{x}_{Ht}(\boldsymbol{m})[\sum_{m'_H}\sum_{m'_G} \tilde{F}_H(m_H, m_G, m'_H, m'_G) V_{2Ht}(m'_H, m_F, m'_G) - 0] - \frac{\tilde{\alpha}_H}{\tilde{\gamma}_H}\tilde{x}_{Ht}^{\tilde{\gamma}_H}\}. \quad \text{(B.1)}$$

The innovation decision rule of Home entrants is hence

$$\tilde{x}_{Ht}(\boldsymbol{m}) = (\frac{\sum_{m'_H}\sum_{m'_G} \tilde{F}_H(m_H, m_G, m'_H, m'_G) V_{2Ht}(m'_H, m_F, m'_G)}{\tilde{\alpha}_H})^{\frac{1}{\tilde{\gamma}_H - 1}}. \quad \text{(B.2)}$$

For Home leaders, there are two extra terms on the RHS of Hamilton-Jacobi-Bellman equation compared to the baseline model: $\tilde{x}_{Ht}(\boldsymbol{m})[\sum_{m'_H}\sum_{m'_G} \tilde{F}_H(m_H, m_G, m'_H, m'_G)V_{1Ht}(m'_H, m_F, m'_G) - V_{1Ht}(\boldsymbol{m})]$ and $\tilde{x}_{Ft}(\boldsymbol{m})[\sum_{m'_H}\sum_{m'_G} \tilde{F}_H(m_H, m_G, m'_H, m'_G)V_{1Ht}(m'_H, m_F, m'_G) - V_{1Ht}(\boldsymbol{m})]$. The innovation problem of Home followers is also extended with two additional terms on the RHS of Bellman equation: $\tilde{x}_{Ht}[0 - V_{2Ht}(\boldsymbol{m})] + \tilde{x}_{Ft}[0 - V_{2Ht}(\boldsymbol{m})]$. For the evolution of the technology gap distribution and aggregate growth, any terms that are associated with followers will carry an extra $\tilde{x}_c$. Aggregate innovation expenditure now also includes the entrants' innovation costs. Assume that entrants do not produce goods before they replace followers.

It is straightforward that if globalization drives down the value of followers, entrants decrease innovation since the value from entering the market decreases. Therefore, globalization contributes to declining entry. Though there is a subtle effect that less entry increases follower value since they are less likely to be replaced, the quantitative magnitude of this effect is small. In summary, incorporating endogenous entry and exit into the baseline model allows for an explanation of additional secular trends, such as the declining entry rate and the share of young firms in the overall economy. These trends are discussed in Akcigit and Ates (2023).

This setup essentially allows for a constant number of firms due to endogenous entry and exit. This could be extended to allow an endogenous number of firms by introducing fixed operational costs in each market. If firms' profits cannot cover these costs, they become dormant. This could explain findings by Amiti and Heise (2021), showing that increased import competition leads to higher domestic concentration in U.S. manufacturing. This occurs as harsher competition reduces profits, pushing some firms to dormancy, and thus, increasing the market share for active firms. However, my research extends beyond manufacturing and the U.S., and my baseline model aligns with my facts. Therefore, I include the discussion on entry and exit in the Appendix.

B.3 Endogenous Choice of Incremental or Radical Innovation

In the baseline model, firms face uncertainty regarding the outcome of future innovation. There is a probability that an innovation will be radical (quick catch-up), leading to a significant improvement in productivity, while there is also a probability that an innovation will only be incremental (slow catch-up), resulting in a small step increase in productivity denoted by λ. While this uncertainty aligns with the reality that firms struggle to predict innovation outcomes, it is plausible that firms endogenously decide whether to pursue incremental or radical innovation. Therefore, I extend the baseline model to incorporate this endogenous choice and examine the robustness of the baseline results to this extension.

Assume that firm innovations' Poisson arrival rate $x^p_{ict}(\boldsymbol{m})$ is determined by their innovation investment $R^p_{ict}(\boldsymbol{m}) \equiv \frac{\alpha^p_{ic}}{\gamma^p_{ic}}(x^p_{ict}(\boldsymbol{m}))^{\gamma^p_{ic}} Y_{ct}$, and successful innovation yields a productivity increase following a probability function $F^p_{ic}(\boldsymbol{m}, \boldsymbol{m'})$, where $p \in \{r, i\}$, r denotes radical innovation and i denotes incremental innovation. Note that $x^p_{ict}(\boldsymbol{m}) = 0$ if $R^p_{ict}(\boldsymbol{m}) > \chi^p_{ic}\Pi_{ict}(\boldsymbol{m})Y_{ct}$, where χ^p_{ic} mimics a (borrowing) constraint for innovation investment. While the baseline model assumes that innovation costs are not bound by any constraints (e.g., financial constraints), in reality such constraints often exist. In particular, radical innovation is costlier and less likely to be successful, which could result in a tighter (financial) constraint for radical innovation.

Taking as given other firms' decisions, the value function of the Home leader is

$$
\begin{aligned}
r_{Ht}V_{1Ht}(\boldsymbol{m}) - \dot{V}_{1Ht}(\boldsymbol{m}) = & \max_{x^i_{1Ht}(\boldsymbol{m}), x^r_{1Ht}(\boldsymbol{m}) \in [0,\bar{x}]} \{\Pi_{1Ht}(\boldsymbol{m})P_{Ht}Y_{Ht} \\
&+(x^i_{1Ht}(\boldsymbol{m}) + \iota \cdot \mathbb{1}_{m_G<0} \cdot (1-\nu))[\sum_{\boldsymbol{m}'} F^i_{1Ht}(\boldsymbol{m},\boldsymbol{m}')V_{1Ht}(\boldsymbol{m}') - V_{1Ht}(\boldsymbol{m})] - P_{Ht}R^i_{1Ht}(\boldsymbol{m})] \\
&+(x^r_{1Ht} + \iota \cdot \mathbb{1}_{m_G<0} \cdot \nu)[\sum_{\boldsymbol{m}'} F^r_{1Ht}(\boldsymbol{m},\boldsymbol{m}')V_{1Ht}(\boldsymbol{m}') - V_{1Ht}(\boldsymbol{m})] - P_{Ht}R^r_{1Ht}(\boldsymbol{m})] \\
&+(x^i_{2Ht}(\boldsymbol{m}) + (\kappa \cdot \mathbb{1}_{m_H>0} + \iota \cdot \mathbb{1}_{m_G<0}) \cdot (1-\nu))[\sum_{\boldsymbol{m}'} F^i_{2Ht}(\boldsymbol{m},\boldsymbol{m}')V_{1Ht}(\boldsymbol{m}') - V_{1Ht}(\boldsymbol{m})] \\
&+(x^r_{2Ht}(\boldsymbol{m}) + (\kappa \cdot \mathbb{1}_{m_H>0} + \iota \cdot \mathbb{1}_{m_G<0}) \cdot \nu)[\sum_{\boldsymbol{m}'} F^r_{2Ht}(\boldsymbol{m},\boldsymbol{m}')V_{1Ht}(\boldsymbol{m}') - V_{1Ht}(\boldsymbol{m})] \\
&+\sum_{i'=1,2}(x^i_{i'Ft} + (\kappa \cdot \mathbb{1}_{m_F>0} + \iota \cdot \mathbb{1}_{m_G>0}) \cdot (1-\nu))[\sum_{\boldsymbol{m}'} F^i_{i'Ft}(\boldsymbol{m},\boldsymbol{m}')V_{1Ht}(\boldsymbol{m}') - V_{1Ht}(\boldsymbol{m})] \\
&+\sum_{i'=1,2}(x^r_{i'Ft} + (\kappa \cdot \mathbb{1}_{m_F>0} + \iota \cdot \mathbb{1}_{m_G>0}) \cdot \nu)[\sum_{\boldsymbol{m}'} F^r_{i'Ft}(\boldsymbol{m},\boldsymbol{m}')V_{1Ht}(\boldsymbol{m}') - V_{1Ht}(\boldsymbol{m})],
\end{aligned}
\tag{B.3}
$$

where ν (or $1-\nu$) represents the probability of getting knowledge spillovers that help radical (or incremental) innovation, and similarly for other firms. These equations yield the following optimal innovation decisions:

$$
x^p_{i'ct}(\boldsymbol{m}) = \begin{cases} 0 & \text{if } R^p_{i'ct}(\boldsymbol{m}) > \chi^p_{i'c}\Pi_{i'ct}(\boldsymbol{m})Y_{ct}, \\ \left(\frac{\sum_{\boldsymbol{m}'} F^p_{i'ct}(\boldsymbol{m},\boldsymbol{m}')V_{i'ct}(\boldsymbol{m}') - V_{i'ct}(\boldsymbol{m})}{\alpha^p_{i'c}P_{ct}Y_{ct}}\right)^{\frac{1}{\gamma^p_{i'c}-1}} & \text{otherwise,} \end{cases}
\tag{B.4}
$$

where $p \in \{i, r\}, c \in \{H, F\}, i' \in \{1, 2\}$. The model setup indicates that the relative incentive to do incremental or radical innovation depends on the extra value from successful innovation. Suppose that radical innovation closes the technology gap between a firm and the domestic or global leader, while incremental innovation increases the firm's productivity by λ. In the context of globalization, where foreign competition intensifies for OECD firms due to the loss of global technological advantage, the expected extra profit from successful radical innovation will decrease more than the expected extra profit from successful incremental innovation. As a result, the incentive for OECD followers to pursue radical innovation is reduced, leading to a slowdown in productivity growth and an increase in domestic concentration. Conversely, when globalization creates a larger foreign market for OECD firms, there might be a greater willingness to engage in radical innovation. However, given that the current production profits of OECD followers are more likely to be affected by foreign competition (due to its low export intensity as discussed in the main text), they are more likely to face binding (financial) constraints, making it difficult for them to pursue radical innovation. The quantitative results demonstrate that this model extension strengthens the baseline findings, assuming that $\chi_{ic}^r < \chi_{ic}^i$ and $\alpha_{ic}^r > \alpha_{ic}^i$.

B.4 International Knowledge Spillovers Endogenously Vary with Trade

In the baseline model, international knowledge spillovers can be from trade flows, migration, etc. Some papers instead empirically or theoretically focus on one specific channel, trade flows (e.g., Buera and Oberfield (2020)). One may want to know whether international knowledge spillovers that endogenously vary with trade alters the model implications. To this end, I model that firms pay per-period fixed export costs to export and that domestic firms can only get international knowledge spillovers from foreign firms that sell in the domestic market. The declining iceberg trade costs endogenously increase international knowledge spillovers by inducing more firms to export.

Specifically, firms have to pay a per-period fixed export cost f_c^{ex} in units of labor to export. As a result, only a portion of firms can generate positive export profits after accounting for fixed export costs, resulting in only a portion of firms exporting. Only firms that export can generate international knowledge spillovers for foreign firms as long as their productivity is higher. Conditional on exporting, leaders (followers) give international knowledge spillovers with probability ι^l (ι^f). The Home intermediate production decision now incorporates an export decision $\zeta_{iHt}^*(\boldsymbol{m})$. It can be shown that $\zeta_{iHt}^*(\boldsymbol{m}) = 1$ if $(p_{iHt}^*(\boldsymbol{m}) - \frac{w_{Ht}}{q_{iHt}(\boldsymbol{m})})y_{iHt}^*(\boldsymbol{m}) \geq w_{Ht} f_H^{ex}$, where $\boldsymbol{m} = \{m_H, m_F, m_G\}$. The VFI, evolution of the technology gap distribution and aggregate growth in this alternative setup replace the $\iota \cdot \mathbb{1}_{m_G<0}$ in the baseline model with $\underbrace{\iota^l \cdot \mathbb{1}_{m_G<0} \cdot \mathbb{1}_{\zeta_{1H}^*=1}}_{\textbf{international spillover from F leader}} + \underbrace{\iota^f \cdot \mathbb{1}_{m_G+m_F<0} \cdot \mathbb{1}_{\zeta_{2H}^*=1}}_{\textbf{international spillover from F follower}}$ for Home firms. Foreign is analogous.

The declining iceberg trade costs induce more Home firms to become exporters, especially firms with relatively low global technological advantages ($m_G > 0$ but m_G relatively low). Therefore, there are more international knowledge spillovers from firms with relatively low global technological advantage. Symmetrically, Foreign firms with relatively low global technological advantage ($m_G < 0$ but close to 0) are more able to become exporters and provide knowledge spillovers to Home firms. Therefore, declining iceberg trade costs generate more spillovers around $m_G = 0$, consistent with the baseline model in which firms around $m_G = 0$ are more affected by international knowledge spillovers. In contrast, firms with large global technological advantages generate much smaller increases in international spillovers since their exporting probability increases by less (they are exporters before globalization). The quantitative results are robust under this alternative specification. However, the explanatory power of globalization is smaller than the baseline findings, suggesting that other sources of knowledge spillovers also play a non-negligible role.

B.5 State-dependent Knowledge Spillovers

Recent research by König et al. (2022) suggests that more technologically backward firms may be more likely to receive knowledge spillovers. Therefore, I extend the model to examine the robustness of the baseline results to this alternative specification. Specifically, I replace the parameters κ and ι with $\kappa(\boldsymbol{m})$ and $\iota(\boldsymbol{m})$. Next, I introduce a uniform increase in $\iota(\boldsymbol{m})$ for all states $\boldsymbol{m}$ to represent globalization. The recalibrated results indicate that when more backward firms are more likely to receive knowledge spillovers, their estimated innovation incentives are lower than those of their counterparts in the baseline model. Overall, the quantitative results remain robust under this alternative specification.

B.6 Knowledge Spillovers directly Close the Technology Gap

Motivated by Akcigit and Ates (2023), knowledge spillovers could exclusively close the technology gap between backward firms and leading firms, rather than allowing for the possibility of improving firms' productivity gradually. To this end, I revise the model to incorporate domestic and international knowledge spillovers that directly close the domestic and global technology gaps. Specifically, from the perspective of Home firms, the effect of knowledge spillovers is captured through the function $\hat{F}_{iH}(m_H, m_G, m'_H, m'_G)$:

$$\hat{F}_{1H}(m_H, m_G, m'_H, m'_G) = \begin{cases} \iota & \text{if } m'_H = \min\{m_H + |m_G|, \bar{m}_H\}, m'_G = 0, \text{ and } m_G < 0, \\ 0 & \text{otherwise.} \end{cases}$$

$$\hat{F}_{2H}(m_H, m_G, m'_H, m'_G) = \begin{cases} \kappa & \text{if } m'_H = 0, m'_G = m_G, \text{ and } m_H > 0 \\ \iota & \text{if } m'_H = \min\{|m_G|, \bar{m}_H\}, m'_G = 0, m_H > 0 \text{ and } m_G < 0, \\ 0 & \text{otherwise.} \end{cases}$$

The value function of Home leaders is then revised accordingly:

$$\begin{aligned} r_{Ht}V_{1Ht}(\boldsymbol{m}) - \dot{V}_{1Ht}(\boldsymbol{m}) = &\max_{x_{1Ht}(\boldsymbol{m})\in[0,\bar{x}]} \{\Pi_{1Ht}(\boldsymbol{m})P_{Ht}Y_{Ht} - P_{Ht}R_{1Ht}(\boldsymbol{m}) \\ &+ (x_{1Ht}(\boldsymbol{m}))[\sum_{m'_H}\sum_{m'_G} F_{1H}(m_H, m_G, m'_H, m'_G)V_{1Ht}(m'_H, m_F, m'_G) - V_{1Ht}(\boldsymbol{m})] \\ &+ (x_{2Ht}(\boldsymbol{m}))[\sum_{m'_H}\sum_{m'_G} F_{2H}(m_H, m_G, m'_H, m'_G)V_{1Ht}(m'_H, m_F, m'_G) - V_{1Ht}(\boldsymbol{m})] \\ &+ (x_{1Ft}(\boldsymbol{m}))[\sum_{m'_F}\sum_{m'_G} F_{1F}(m_F, m_G, m'_F, m'_G)V_{1Ht}(m_H, m'_F, m'_G) - V_{1Ht}(\boldsymbol{m})] \\ &+ (x_{2Ft}(\boldsymbol{m}))[\sum_{m'_F}\sum_{m'_G} F_{2F}(m_F, m_G, m'_F, m'_G)V_{1Ht}(m_H, m'_F, m'_G) - V_{1Ht}(\boldsymbol{m})] \\ &+ \sum_{i=1,2}\sum_{c\in\{H,F\}}[\sum_{m'_c}\sum_{m'_G} \hat{F}_{ic}(m_c, m_G, m'_c, m'_G)V_{1Ht}(m'_c, m_{c'}, m'_G) - V_{1Ht}(\boldsymbol{m})]\} \end{aligned} \tag{B.5}$$

and similarly for other firms. The quantitative results indicate a more negative growth effect of globalization. In the baseline model, increasing international knowledge spillovers mainly negatively affects firms which are close to global neck-and-neck states due to the incremental increases in firm productivity, as demonstrated in section 3.1. However, in this alternative setup, the increasing international knowledge spillovers also harm firms that are enjoy significant technology leads, reducing their escape-competition motive. On the other hand, the effect on domestic concentration mainly depends on the change in production profits given the technology gap and the changing distribution over technology gaps, which is disciplined by the data. Therefore, the effect on domestic concentration is quantitatively consistent with the baseline findings.

B.7 Fraction of Leaders Is 5% or 1 instead of 1%

The model incorporates an oligopolistic competition structure, which allows for a finite number of firms. However, concerns have been raised regarding the abstraction of the firm size distribution, which may undermine the credibility of the quantitative results. To address this concern, I vary the mass of leaders and followers in the model. In the baseline model, leaders account for 1 percent of the total number of firms, but I examine the robustness of the quantitative findings when leaders account for 5 percent of all firms.

I also assume that only the largest firm is the leader, while all other firms are followers. Consistent with Olmstead-Rumsey (2022), all other firms can be considered as a follower (second largest firm) and a competitive fringe. Each industry contains a competitive fringe of firms that can produce a perfect substitute to the follower with marginal cost η, making the follower's price equal to η. All data moments are recalculated for each classification of leaders and followers. The corresponding reconstructed empirical facts remain consistent with the baseline data moments, as indicated in section 4.1. The quantitative results demonstrate that the leader-follower setup does not affect the baseline findings, thereby enhancing the credibility of the quantitative results.

Of note, the number of firms in a market does indeed influence the nature of strategic competition. Intuitively, assuming that only a leader and a follower exist in an industry-country pair essentially assumes that all firms within the leader or follower group are identical or capable of colluding. Due to collusion, firms choose a single price to maximize their group profits, resulting in a larger group market share and group profit than their individual market shares and profits. And the presence of more firms in a market would reduce the collusion profits. However, regardless of the number of firms modeled in a market, data moments are necessary to discipline the model. Specifically, we focus on the aggregate markup, the relative firm size and innovation differences over measured technology gaps. The consistent quantitative findings are, in fact, a natural outcome of the consistent data moments across different classifications of leaders and followers.

C Computation Algorithm

C.1 Computation Algorithm for BGP

There are two key challenges in numerically solving the model. First, the presence of three technology gaps makes it complicated to solve compared to other models with only one technology gap, especially due to the special cases for the domestic neck-and-neck states and boundary states when computing the value function iteration and the evolution of the distribution of technology gaps, as indicated by the computation in Akcigit and Ates (2023) and Olmstead-Rumsey (2022). Second, the asymmetric country setup, rich innovation process, multi-firm production, and nonlinear relationships due to endogenous markups and strategic innovation behavior make it challenging to pin down the equilibrium. I overcome these difficulties by using various techniques (choice of state space and numeraire, indicator functions, etc) and provide a tractable computation algorithm.

Solution Method. There are seven steps for solving a stationary BGP equilibrium.

Step 1. Set up the technology gap space $\boldsymbol{m} = \{m_H, m_F, m_G\}$. I set up the state space to be sufficiently large such that further enlarging the state space does not significantly change the quantitative results under the same targeted data moments. Specifically, $\bar{m}_c = 12, c \in \{H, F\}, \bar{m}_G = 10$.[54] Unlike existing papers that set $-\bar{m}_c \leq m_c \leq \bar{m}_c$, I set $0 \leq m_c \leq \bar{m}_c$ and characterize the problems of the leader and follower separately, which helps reduce the computational burden significantly in the setup with multiple state variables.

Step 2. Set initial guesses for Foreign wages w_F^{old}, aggregate expenditure $P_c Y_c^{old}$ and interest

[54]Note that only when $m_H = \bar{m}_H$ and $m_G = \bar{m}_G$ does the Home leader's innovation incentive diminish to 0. Otherwise, the Home leader has a positive innovation incentive.

rates r_c^{old} in each country. There are two tricks. The first is choosing the Home wage as the numeraire in the model instead of using aggregate prices. This helps generate $r_{ct} = \rho$ in BGP equilibrium such that the interest rate r_{ct} is directly pinned down without any iteration. The second is to iterate $P_c Y_c^{old}$ as a single object instead of iterating each term separately.

Step 3. Solve the static decisions (production and pricing) of firms given the initial guesses. Then solve the value functions jointly for both countries by backward induction and the uniformization method developed by Acemoglu and Akcigit (2012). This process yields the optimal innovation policies as well as the static decisions of firms in each state. I ensure that $\max_{\boldsymbol{m}} ||v_{\boldsymbol{m}}^{new} - v_{\boldsymbol{m}}^{old}|| \leq$ 1e-08. The trick here is the uniformization method, which helps ensure the convergence of the value function iteration and greatly reduces the time required to find the convergence.

Step 4. Compute the stationary distribution of firms over technology gaps. I impose that the total mass of industries is one. Initially guess a mass of industries and solve the distribution of firms by using the "evolution equations" across the technology gaps. Keep iterating until the distribution becomes stationary. I then compute the aggregate growth rate using innovation decisions and the stationary distribution. Note that the boundary cases are considered in the $F_{ic}(m_c, m_G, m'_c, m'_G)$ function where $c \in \{H, F\}$, as discussed before, and the addition of a set of indicator functions also reduces the occurrence of special cases (boundary states or neck-and-neck states).

Step 5. Impose market clearing conditions. Given firms' static decisions and the stationary distribution of firms, compute $P_c Y_c^{new}$ and w_F^{new} by imposing labor market clearing conditions and the balanced trade condition. Check whether $w_F^{new} - w_F^{old} \leq$ 1e-06, $P_c Y_c^{new} - P_c Y_c^{old} \leq$ 1e-06, $c \in \{H, F\}$. If not, update w_F^{old} and $P_c Y_c^{old}$, and restart from the third step until they converge.

Step 6. After solving the model, compute firm-level variables of interest based on the steady-state distribution over technology gaps. Only when it is impossible to compute variables of interest based on the steady-state of the model, simulate a discrete-time version of the model with 10 subperiods per year for a panel of 10,000 firms in each country for 300 years after the model reaches the steady-state distribution over technology gaps.

Step 7. Compare model moments to targeted data moments. Search over the parameter space to minimize the objective function $\min_{\boldsymbol{\theta}} \sum_{k=1}^{K} p_k \frac{|\text{model}_k(\boldsymbol{\theta}) - \text{data}_k|}{\frac{1}{2}|\text{model}_k(\boldsymbol{\theta}) + \text{data}_k|}$.

Estimation Routine. I choose a vector of parameters $\boldsymbol{\theta}^*$ to minimize the objective function $\min_{\boldsymbol{\theta}} \sum_{k=1}^{K} p_k \frac{|\text{model}_k(\boldsymbol{\theta}) - \text{data}_k|}{\frac{1}{2}|\text{model}_k(\boldsymbol{\theta}) + \text{data}_k|}$, where k denotes the kth moment in the model and the data, K denotes the total number of moments, and p_k denotes the weight of moment k. I set the weights p_k such that the productivity growth rate, leader premium in sales, relative productivity between two countries, and export intensity are weighted 3 times more than the other moments, given that these moments are the key moments of interest.

I proceed in two steps to minimize the objective function and make sure the global minimum is reached, motivated by Afrouzi et al. (2023). First, I construct 200 quasi-random vectors of parameters from a deterministic sequence, which is designed to cover the parameter space evenly. After computing the objective function at those points, I choose the 30 vectors of parameters with the lowest objective values. Second, I solve the model for each of the 30 vectors of parameters and select the local minimum with the lowest objective value. I also check whether using a different initial guess of wages or aggregate expenditure leads to different implications of globalization and find that the results in the main text are robust to alternative initial guesses.

C.2 Computation Algorithm for Transition Dynamics

I assume that the economy begins in the initial BGP. At period $t = 1$, it is hit by a permanent and unexpected gradual 15-year decrease in iceberg trade costs and increase in international knowledge spillovers. The economy will converge to a new BGP at period T, for some T large enough. I solve a discrete version of the model with small time increments $\Delta t = 0.1$ and proceed in five steps.

Step 1. Solve the initial BGP and the new BGP.

Step 2. Guess a wage path $\boldsymbol{w_{Ft}} = \{w_{F1}, w_{F1+\Delta t}, w_{F1+2*\Delta t}, ..., w_{FT}\}$, aggregate revenue path for $\boldsymbol{P_{Ht}Y_{Ht}}, \boldsymbol{P_{Ft}Y_{Ft}}$, and interest rate path $\boldsymbol{r_{Ht}}, \boldsymbol{r_{Ft}}$, with $\boldsymbol{w_{Ht}} \equiv \boldsymbol{1}$.

Step 3. Solve the firm static problems in each period given the guesses. Given the steady state values $v_{m,T}$ assumed at T (new BGP values), solve for innovation policies at $T - \Delta t$. Specifically,

$$x_{1HT-\Delta t}(\boldsymbol{m}) = \left(\exp(-r_{HT}\Delta t)\frac{\sum_{m'_H}\sum_{m'_G} F_{1H}(m_H, m_G, m'_H, m'_G)v_{1HT}(m'_H, m_F, m'_G) - v_{1HT}(\boldsymbol{m})}{\alpha_{1H}}\right)^{\frac{1}{\gamma_{1H}-1}}. \tag{C.1}$$

Then given the policy functions at $T - \Delta t$ and guessed variables, solve for the value function for Home leader as follow:

$$\begin{aligned}
V_{1HT-\Delta t}(\boldsymbol{m}) = \max_{x_{1HT-\Delta t}(\boldsymbol{m})\in[0,\bar{x}]} &\{\Delta t[\Pi_{1HT-\Delta t}(\boldsymbol{m})P_{HT-\Delta t}Y_{HT-\Delta t} - P_{HT-\Delta t}R_{1HT-\Delta t}(\boldsymbol{m}) + exp(-r_{HT}\Delta t)\{\\
&\Delta t \cdot [(x_{1HT-\Delta t}(\boldsymbol{m}) + \iota \cdot \mathbb{1}_{m_G<0})[\sum_{m'_H}\sum_{m'_G} F_{1H}(m_H, m_G, m'_H, m'_G)V_{1HT}(m'_H, m_F, m'_G) - V_{1HT}(\boldsymbol{m})]\\
&+(x_{2HT-\Delta t}(\boldsymbol{m}) + \kappa \cdot \mathbb{1}_{m_H<0} + \iota \cdot \mathbb{1}_{m_G<0})[\sum_{m'_H}\sum_{m'_G} F_{2H}(m_H, m_G, m'_H, m'_G)V_{1HT}(m'_H, m_F, m'_G) - V_{1HT}(\boldsymbol{m})]\\
&+(x_{1FT-\Delta t}(\boldsymbol{m}) + \iota \cdot \mathbb{1}_{m_G>0})[\sum_{m'_F}\sum_{m'_G} F_{1F}(m_F, m_G, m'_F, m'_G)V_{1HT}(m_H, m'_F, m'_G) - V_{1HT}(\boldsymbol{m})]\\
&+(x_{2FT-\Delta t}(\boldsymbol{m}) + \kappa \cdot \mathbb{1}_{m_F<0} + \iota \cdot \mathbb{1}_{m_G>0})[\sum_{m'_F}\sum_{m'_G} F_{2F}(m_F, m_G, m'_F, m'_G)V_{1HT}(m_H, m'_F, m'_G) - V_{1HT}(\boldsymbol{m})]\\
&+V_{1HT}(\boldsymbol{m})\},
\end{aligned} \tag{C.2}$$

and solve for the decision rule and value functions for other firms analogously. Repeat the above and solve the innovation decisions and value functions of firms backwards until $t = 1$.

Step 4. Suppose at $t = 1$, $Q_{H1} \equiv \bar{Q}_1$. Given the sequence of innovation decisions and the evolution of the firm distribution, start from $t = 1$ to obtain the distribution of firms over technology gaps and the sequence of growth rates $g_{ct}, c \in \{H, F\}$ over the transition as well as aggregate variables. Of note, the aggregate productivity growth rate in a non-stationary equilibrium is a weighted average of firm productivity growth rates.

Step 5. Check if the guessed paths of wages, interest rate, and aggregate revenue are consistent with the market clearing conditions. If not, update the paths and repeat from step 3 until the guessed paths converge.

D Additional Quantitative Results

D.1 Heterogeneity among OECD Countries

The quantitative analysis in the main text utilizes European data to parameterize the OECD. A subsequent inquiry arises as to whether the implications for the OECD are affected by the data selection, such as the use of U.S. data potentially yielding different outcomes. I summarize four factors that might lead to divergent implications when using European and U.S. data. (i) **Quick catch-up probabilities**: If followers in the U.S. are more likely to catch up with leaders, the negative growth effect of globalization could be weakened as discussed in section 4.5.1. However, my patent data suggests the quick catch-up probability in the U.S. is low. (ii) **Initial technological distance among firms**: Existing facts suggest that domestic concentration levels and global technological advantages are higher in the U.S. than in Europe. Specifically, U.S. firms appear to be more concentrated in the decreasing portion of the inverted-U curve in both domestic and international markets. The model suggests that globalization in the U.S. weakens domestic competition by shifting the firms' distribution over domestic concentration levels to the right. This makes firms more concentrated in the decreasing part of the inverted-U in the domestic market, potentially impeding growth when compared to Europe. However, a stronger incentive to avoid foreign competition could counter this negative growth effect. This heightened motivation is due to a higher concentration of firms in the increasing part of the inverted-U curve in the global market after globalization. In other words, globalization shifts firms' distribution over global output share to the left, causing firms to concentrate more at the peak and the increasing part of the inverted-U in the international market.(iii) **Import or export exposure**: European countries typically have smaller domestic market sizes, making the market size effect of globalization potentially more significant compared to the U.S. (iv) **Multinational production or exporting**: If U.S. firms are more prone to being multinational firms that generate foreign sales through foreign subsidiaries rather than direct exports, using export intensity as a measure of globalization might underestimate the effect of globalization on domestic concentration. More studies could be conducted in the future as more data becomes available.

D.2 Parameterization Sensitivity Analysis

Table D.1 summarizes the percentage change in each targeted moment in response to a 1% change in each internally estimated parameter, indicating that the internally estimated parameters are indeed closely related to certain specific moments discussed in main text. For example, it shows that a one percentage increase in the foreign labor force L_F (innovation step size λ) leads to a 0.37 (9.51) percentage decrease (increase) in mean global output share (TFP growth rate), and much less change in other targeted moments. It also shows that the innovation cost parameters and quick catch-up probability parameters jointly determine the R&D-to-GDP ratio and innovation rates over measured technology gaps.

D.3 Model Validation for International Spillover Parameter

Figure D.1 plots the density distribution of relative productivity across industries in the data and the model distributions using different values of ι. Relative productivity is the log difference in industry TFP between OECD and ROW.[55] A relative productivity larger than 0 means OECD is more

[55]In the data, industry TFP is constructed using the 2019 EU KLEMS data adjusting for differences in prices, capital utilization, labor quality, resource allocation, and innovation subsidies across countries. In the

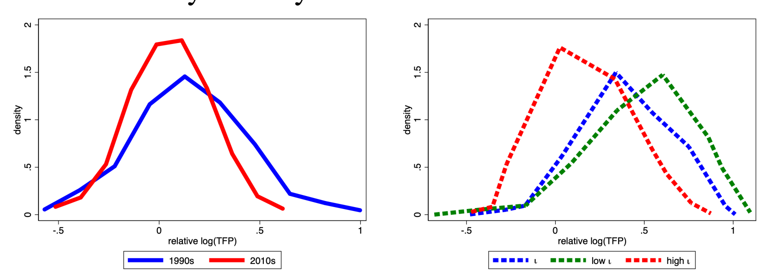
Table D.1: Sensitivity Analysis of Prameterization

Targeted Moments	L_F	ϵ	λ	τ_c	α_{1H}	α_{1F}	α_{2H}	α_{2F}	ϕ_c	δ_c	ι	κ
Mean global output share	-0.37	-0.13	-3.78	-0.02	-0.31	-0.03	0.33	0.02	-3.64	0.39	-0.02	-0.01
Aggregate markup	0.01	-0.36	0.50	0.08	0.00	0.00	0.07	0.00	-0.07	0.00	-0.01	-0.01
TFP growth rate	-0.09	0.02	9.51	-0.06	-0.52	-0.02	-0.14	0.00	0.12	0.03	-0.01	0.03
Mean export intensity	0.07	0.01	-0.93	-0.08	0.08	0.00	-0.01	0.00	0.02	-0.01	0.00	0.01
R&D/GDP in OECD	-0.01	0.18	2.08	-0.02	-0.21	0.02	0.10	0.01	0.21	0.02	0.01	-0.01
R&D/GDP in ROW	-0.31	0.29	4.75	-0.07	-0.12	-0.83	0.05	-0.11	-0.15	-0.01	-0.01	0.00
$\|p90 - p10\|_{1H}$ over domestic gap	-0.14	0.05	5.20	-0.05	-0.49	-0.11	0.28	-0.05	-0.06	1.12	0.03	-0.01
$\|p90 - p10\|_{2H}$ over domestic gap	-0.26	0.19	8.30	-0.07	-0.56	0.10	-0.93	0.12	0.47	0.60	0.22	0.00
$\|p90 - p10\|_{1H}$ over global gap	-0.16	0.03	4.10	-0.04	-0.55	-0.08	0.26	-0.06	-0.04	1.36	0.04	-0.01
$\|p90 - p10\|_{2H}$ over global gap	-0.27	0.17	7.50	-0.06	-0.54	0.12	-1.25	0.09	0.39	0.80	0.23	0.00
Mean (OECD TFP/ROW TFP)	-0.01	0.00	-1.27	-0.01	-0.08	0.00	0.01	0.00	-0.02	0.01	0.01	0.00
Mean leader sales premium	0.16	0.32	4.67	-0.06	0.01	-0.01	0.22	-0.01	-0.23	0.00	-0.03	-0.01

Notes: $i \in \{1, 2\}, c \in \{H, F\}$. This table presents the percentage change in each targeted moment in response to a 1 percent increase in each internal parameter, fixing the other parameters at their estimated value.

productive than ROW. A larger fraction of industries concentrated at high relative productivity levels means more OCED industries have a technological advantage. This figure shows that the initial BGP of the model matches the 1990s distribution, and increasing ι leads to a model distribution closer to the data distribution in the 2010s. A larger ι typically narrows the model industry density and shifts it to the left, indicating ROW technological catchup, while a smaller ι shifts the distribution to the right and leads to larger technology gaps. The changing TFP density distribution in the data indicates a technological convergence story. Figure G.1 plots the data distribution over relative productivity between OECD and ROW every five years to show that the changes in the empirical distribution are not driven by the choice of years for the initial and end periods.

Figure D.1: Industry Density Distribution Over Relative Productivity



(a) Data (b) Model

Notes: Panels (a) and (b) in this figure present the industry density distribution over relative productivity between OECD and ROW in the data and model. The X-axis denotes the log difference in industry TFP between OECD and ROW. The Y-axis denotes the industry density. In panel (a), the blue solid line represents the 1990s data. The red solid line represents the 2010s data. In panel (b), the blue dashed line represents the density distribution along the initial BGP. The red (green) dashed line represents increasing (decreasing) ι by a factor of 3 keeping all other parameters at their initial BGP level.

D.4 Sensitivity Analysis of Implications of Globalization

Since the model indirectly infers international knowledge spillovers, a natural concern arises regarding the quantitative validity of the implications of increasing international knowledge spillovers. To address this concern, I vary the magnitude of globalization by using a range of changes in globalization parameters, instead of specific values as mentioned in the main text, in which the change in the international knowledge spillover parameter ($\Delta\iota$) is set to 0.04 and the change in the trade cost parameter ($\Delta\tau$) is set to -0.08 from the initial to the new BGP. Table D.2 demonstrates that the

model, industry TFP is computed as total output over total employment. Defining industry TFP as the employment- (or sales-) weighted average of TFPQ across firms in the model leads to similar results. More details are in section G of Appendix.

qualitative implications of globalization remain consistent with the baseline results.

Table D.2 also highlights the intriguing non-linear impact of globalization. In particular, it highlights the harsher foreign competition effect relative to larger foreign market size effect of international knowledge spillovers becomes more and more significant as international knowledge spillovers increase. Specifically, first, as the magnitude of international knowledge spillovers rises, the magnitude of the increase in domestic technology gap initially increases, and then decreases. The intuition behind this is as follows: when the increase in international knowledge spillovers is relatively small, OECD firms with a relatively high initial global technological advantage have both the motive to escape competition and benefit from the market size effect. This increases the innovation incentive for OECD firms, especially leaders, and subsequently raises the domestic technology gap. However, as the increase in international knowledge spillovers becomes larger, foreign competition becomes more significant, which reduces leaders' innovation incentive and leads to a smaller increase in the domestic technology gap. The change in the domestic gap then governs the change in domestic concentration and leader premium. Second, the slowdown in productivity growth also exhibits non-linear change for similar reasons as the domestic technology gap. Initially, a small increase in international knowledge spillovers leads to an escape competition motive and a larger market size effect. However, when the international knowledge spillover is high enough, harsher foreign competition negatively impacts productivity growth. Third, as international knowledge spillovers increase, the shrinking global technological advantage of OECD and the shrinking global output share of OECD compared to ROW become more significant. Additionally, the increase in aggregate markup becomes smaller as a response to harsher foreign competition.

As for the declining trade cost force of globalization, Table D.2 shows that the impact of trade costs is quantitatively small, even when there is a significant reduction in trade costs, and no significant patterns are exhibited. As discussed in the main text, the reduction in trade costs supports a divergence story in which industries with a global technological advantage tend to produce and innovate more while industries without a global technological advantage tend to produce less. The aggregate effects depend on which types of industries dominate. The results indicate that when there is a substantial reduction in trade costs, the foreign competition effect is more likely to dominate due to the ROW cost advantage, given its lower wages compared to the OECD.

Table D.2: Implications of Globalization on OECD: A Range of Parameter

	$\Delta\iota$							$\Delta\tau$						
	0.01	0.02	0.03	**0.04**	0.05	0.06	0.07	−0.02	−0.04	−0.06	**−0.08**	−0.10	−0.12	−0.14
Panel A. Technology gaps														
ΔDomestic gap	0.98	1.15	2.23	1.14	1.02	0.93	0.81	0.02	0.02	0.01	0.01	0.01	0.00	0.00
ΔGlobal gap	-0.55	-0.68	-0.77	-0.82	-0.85	-0.87	-0.88	-0.03	-0.05	-0.09	-0.05	-0.05	-0.10	-0.07
Panel B. Uneven firm growth														
ΔLeader sales premium	0.31	0.37	0.54	0.39	0.29	0.23	0.19	0.03	0.02	0.02	0.01	0.01	0.004	0.003
ΔLeader exports premium	0.63	0.75	0.96	0.81	0.59	0.51	0.48	0.02	0.01	0.004	0.002	0.002	0.001	0.001
Panel C. Aggregates														
ΔTFP growth rate,%	-0.45	-0.44	-0.43	-0.42	-0.44	-0.46	-0.48	0.002	0.001	0.001	0.00	0.00	-0.001	-0.001
ΔDomestic concentration	0.04	0.06	0.09	0.06	0.04	0.03	0.02	0.019	0.016	0.013	0.01	0.007	0.002	0.001
ΔGlobal output share	-0.001	-0.006	-0.009	-0.01	-0.012	-0.014	-0.015	0.001	0.001	0.00	0.00	-0.001	-0.001	-0.002
ΔAggregate markup	0.12	0.10	0.09	0.08	0.07	0.06	0.06	0.06	0.04	0.03	0.05	0.04	0.02	0.01

Notes: The columns of this table present the changes in key variables of interest from the initial BGP to the new BGP in the OECD model economy. These changes are driven by a range of changes in individual globalization parameters, while holding the others fixed at their initial values. The detailed analysis of this table is in section D.4.

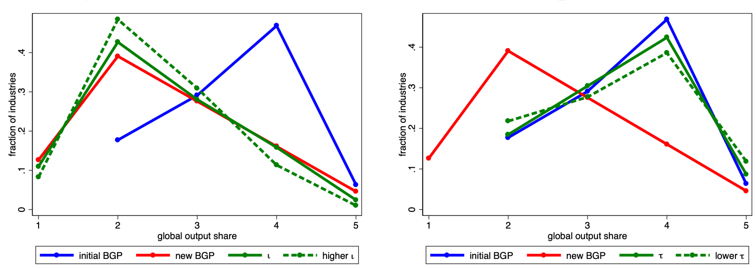
D.5 Exploring the Model Mechanism and Key Model Elements

Figure D.2 examines how the distribution of OECD industries over their global market share changes in response to each force.

Column 6 of Table 4.2 isolates the international business stealing effect (IS) of increasing international knowledge spillovers. It holds the relative wage and relative aggregate expenditure constant at the initial BGP level. Compared to column 4, which includes all the effects of international knowledge spillovers, the international business stealing effect alone predicts a larger decrease in innovation incentives for OECD leaders due to their relatively larger profit loss compared to domestic followers, resulting in a decrease in domestic concentration. Additionally, the international business stealing effect hurts aggregate productivity growth more than the other effects. Columns 7 and 8 of Table 4.2 illustrate the market size (MS) and import competition (IC) effects of decreasing trade costs. While the reduction in trade costs, as well as changes in relative wages and aggregate expenditure, are uniform across industries, their effects vary based on each industry's initial global technological advantage. Industries with a high initial advantage see a larger increase in export profits compared to domestic profit loss, resulting in a 'net' market size effect. In contrast, industries with a low initial advantage witness a smaller rise in export profits relative to domestic profit loss, leading to a 'net' import competition effect. These findings imply that the market size effect tends to predict a more significant increase in innovation for leaders than for followers, while the import competition effect suggests the opposite.

Table D.3 summarizes the key ingredient of the model in driving the quantitative results.

Figure D.2: Industry Mass Distribution Over Global Output Share of Home (OECD)



(a) increase ι (b) decrease τ

Notes: Panel (a) and (b) present the industry distribution over OECD global output shares when separately changing the international knowledge spillover parameter ι and the iceberg cost parameter τ in the model. The blue (red) line represents the initial (new) BGP. The green solid line represents changing one parameter from its initial BGP value to new BGP value. The green dashed line represents increasing (decreasing) one parameter from its initial BGP value to a value that is double (half) the new BGP value. The X-axis partitions the range of X into 5 equal lengths. The Y-axis denotes the fraction of industries in each group.

D.6 Policies Implications

Table D.4 displays policy implications.

D.7 Transition Dynamics and Model Mechanism Validation

Figure D.3 plots the effects of globalization in the transition dynamics. Table D.7 provides evidence supporting the model's mechanism, with both the model and data presenting similar predictions. Comprehensive data results are given in Table D.5 and Table D.6.

In Table D.5, Panels A1 and B1 demonstrate that in the early 2000s, an increase in export intensity (reflecting the market size effect of globalization) leads to a larger increase in patents and citations among leaders than followers; however, for all firms, there is a reduction in patents and citations in later periods. These results are not driven by the financial crisis. To address concerns

Table D.3: The Role of the Main Model Elements (BGP Analysis)

	(1) Globalization	(2) No domestic competition	(3) Quick catch-up domestic	(4) Quick catch-up int'l	(5) Different tech gap domestic	(6) Different tech gap int'l	(7) No int'l spillover	(8) Productivity fixed
Panel A. Technology gaps								
ΔDomestic gap	1.15		-0.43	-0.11	0.19	0.16	-0.21	
ΔGlobal gap	-0.82	-0.20	-0.65	-0.49	-0.53	-0.15	-0.29	
Panel B. Uneven firm growth								
ΔLeader sales premium	0.44		-0.07	-0.01	0.21	0.18	-0.14	0.04
ΔLeader exports premium	0.81		-0.19	-0.03	0.26	0.22	-0.15	-0.05
Panel C. Aggregates								
ΔTFP growth rate,%	-0.42	-0.13	0.15	0.08	0.02	0.01	-0.01	
ΔDomestic concentration	0.07		-0.04	-0.01	0.05	0.03	-0.02	0.01
ΔGlobal output share	-0.01	-0.004	-0.008	-0.007	-0.007	-0.003	-0.005	-0.001
ΔAggregate markup	0.14	-0.02	-0.02	-0.01	0.09	-0.01	-0.03	-0.001

Notes: This table presents the effect of globalization on OECD in the baseline model (column 1) and counterfactuals by using alternative models or parameters (other columns).

Table D.4: Unilateral Policy Implications (BGP Analysis)

	productivity growth change, %
Panel A. Globalization	
baseline model	-0.42
Panel B. Globalization + balanced government transfer	
innovation policy	
subsidy to follower	-0.13
subsidy to all firms	-0.20
trade policy	
export subsidy to follower	-0.42
tariff increase	-0.43
corporate tax policy	
profit tax on leader	-0.42
Panel C. Globalization + costless technology transfer	
increase domestic transfer $\kappa \times 5$	0.05
decrease international transfer $\iota/5$	0.01

Notes: Panel A shows the long-run productivity growth effect of globalization in the baseline model. Panel B presents the long-run productivity growth effect of globalization with policies that balance government transfers. Panel C shows the long-run productivity growth effect of globalization with costless technology transfers.

about the endogeneity of export intensity to firm innovation, I use export intensity in other countries to measure a country's export intensity, as suggested by Autor et al. (2020a), and find similar results, as shown in Panels A2 and B2. The table also demonstrates that the results are robust to alternative measures of innovation, as shown in Panels C, D and E. Interestingly, the results suggest that in response to an increase in export intensity, leaders may conduct more incremental innovation as opposed to radical innovation, which further strengthens the mechanism that the market size effect could harm productivity growth.

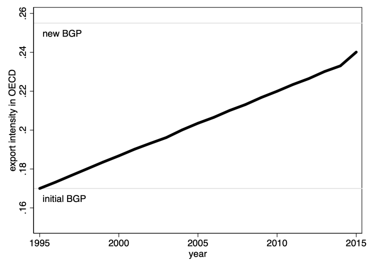
Table D.6 shows that an increase in import intensity (reflecting the foreign competition effect) leads to a larger decrease in various measures of innovation among leaders compared to followers, consistent with the baseline quantitative results in the main text.

E Additional Empirical Facts

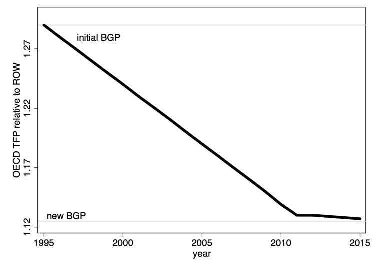
E.1 Additional Motivating Trends

Figure E.1 illustrates an increase in non-OECD citations using alternative measures. Similar patterns are observed in the European Patent Office. Further details are available upon request.

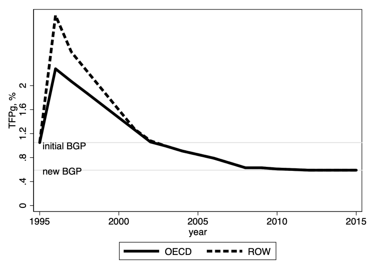
Figure D.3: Transition Dynamics



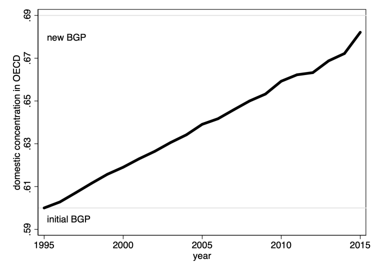
(a) export intensity



(b) relative TFP



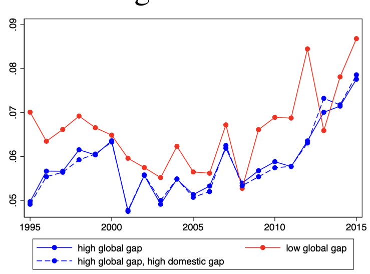
(c) TFP growth



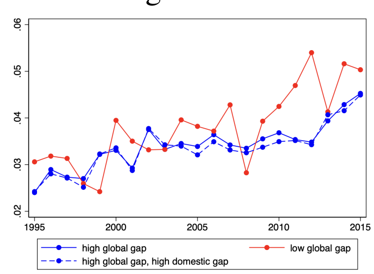
(d) domestic concentration

Notes: Panels (a) and (b) present the evolution of TFP growth in OECD and ROW, along with domestic concentration in OECD for the first 20 years of the transition. The initial and new BGP values induced solely by globalization are also included.

Figure E.1: Additional Motivating Trends



(a) Share of non-OECD citations among all citations



(b) Share of non-self citations from non-OECD, non-China sources

Notes: This figure categorizes industries into high and low initial global technology gaps based on the median level of global output share prior to 2005 for each country. Among industries with a high global technology gap in a country, they are further classified into high and low initial domestic technology gaps based on the 75th percentile of domestic concentration before 2005. It highlights patterns in the manufacturing and ICT service sectors, which are tradable and account for approximately 80 percent of patenting activities in the total economy. The plot includes data from the U.S. and twelve European countries, weighted by country-industry-specific output. The left panel plots the fraction of citations a firm receives from non-OECD foreign firms among all citations it receives. The right panel plots the fraction of citations a firm receives from non-OECD non-China foreign firms among non-self citations it receives.

E.2 Additional Facts On Innovation Over Technology Gaps

E.2.1 Robustness Checks and Reconcile the Existing Findings

I conducted additional checks as listed below and most results are qualitatively consistent with the above findings. Specifically, (i) **Controlling for country-year fixed effects, firm fixed effects, and firm-level characteristics** (leverage and total assets) to address concerns that some firms may be more likely to innovate due to factors unrelated to technological differences (Figure E.5). (ii) **Alternative definitions of leaders and followers**: leaders are the top 5% or the sole leading firm per industry-country pair (Figures E.7 and E.8). (iii) **Alternative measures of innovation**:

Table D.5: Export Intensity and Innovation: Leaders Are Top 1 Percent

	Initial Period		End Period		End Period before 2008	
	Leader	Follower	Leader	Follower	Leader	Follower
Panel A1: Standardized Patent Citations						
$\Delta\text{EXO}_{t-5,t}$	1.700***	0.047***	-8.089***	-0.019***	-4.575***	-0.294***
	(0.234)	(0.005)	(0.404)	(0.004)	(0.672)	(0.004)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.94	.7	.97	.82	.99	.89
Panel B1: Standardized Number of Patents						
$\Delta\text{EXO}_{t-5,t}$	3.530***	0.147***	-59.469***	-0.684***	-2.642	-0.560***
	(0.319)	(0.008)	(1.857)	(0.014)	(2.389)	(0.010)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.97	.8	.63	.56	.94	.86
Panel C1: Standardized Citations of Radical Patents						
$\Delta\text{EXO}_{t-5,t}$	-5.799***	-0.050	-33.485***	-4.035***	-26.876***	-9.989***
	(1.032)	(0.043)	(1.303)	(0.060)	(3.328)	(0.223)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.48	.69	.66	.58	.66	.56
Panel D1: Standardized Number of Radial Patents						
$\Delta\text{EXO}_{t-5,t}$	-3.233***	-0.038***	-18.705***	-0.335***	-11.215***	-0.218***
	(0.278)	(0.004)	(0.876)	(0.010)	(1.609)	(0.013)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.9	.89	.88	.41	.98	.68
Panel E1: Have Intangibles Or Not						
$\Delta\text{EXO}_{t-5,t}$	0.041***	0.038*	-0.033	-0.007	-0.031	0.003
	(0.004)	(0.023)	(0.034)	(0.005)	(0.078)	(0.011)
Obs.	115942	9020110	134262	9131985	43390	3205704
Adjusted R^2	.75	.71	.72	.74	.84	.84
Panel A2: Standardized Patent Citations						
$\Delta\text{EXO\_IV}_{t-5,t}$	1.880***	-0.259***	-9.365***	-0.265***	-8.364***	-0.244***
	(0.538)	(0.009)	(0.840)	(0.008)	(1.414)	(0.009)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.94	.71	.97	.82	.99	.89
Panel B2: Standardized Number of Patents						
$\Delta\text{EXO\_IV}_{t-5,t}$	7.527***	-0.747***	-11.721***	-1.674***	-62.512***	-1.670***
	(0.731)	(0.017)	(3.885)	(0.030)	(5.026)	(0.022)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.97	.8	.62	.56	.94	.86
Panel C2: Standardized Citations of Radical Patents						
$\Delta\text{EXO\_IV}_{t-5,t}$	-10.986***	-2.440***	-23.996***	-0.627***	-83.946***	-3.202***
	(2.366)	(0.090)	(2.706)	(0.129)	(7.282)	(0.492)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.48	.69	.66	.58	.62	.56
Panel D2: Standardized Number of Radial Patents						
$\Delta\text{EXO\_IV}_{t-5,t}$	0.318	-0.098***	-17.060***	-0.837***	-69.154***	-0.302***
	(0.639)	(0.009)	(1.806)	(0.022)	(3.288)	(0.029)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.9	.89	.88	.41	.98	.68
Panel E2: Have Intangibles Or Not						
$\Delta\text{EXO\_IV}_{t-5,t}$	0.157***	0.054	0.068	-0.101***	-0.941***	-0.256***
	(0.008)	(0.052)	(0.084)	(0.011)	(0.161)	(0.025)
Obs.	115942	9020110	134262	9131985	43390	3205704
Adjusted R^2	.75	.71	.72	.74	.84	.84

Notes: This table presents regression results of firm innovation measures from year $t-5$ to t against changes in export intensity from year $t-5$ to t in the data. Export intensity is measured in two ways: a country's own export-to-output ratio (Panel A1 to Panel E1) and other countries' export-to-output ratio (Panel A2 to Panel E2) at the industry level. The period is divided into an initial period before 2005, an end period since 2005, and an end period before 2008 (years between 2005 and 2007). The regressions include controls and fixed effects: industry-level export intensity and firm innovation measures at year $t-5$, country-year fixed effects, and firm fixed effects. The regression is weighted by firm sales and industry output. * $p < 0.10$, ** $p < 0.05$,*** $p < 0.01$.

number of patents, whether a firm has intangible assets or not, number of radical patents (those with significant citations), and total citations of radical patents. Due to data limitations on R&D expenditures for European firms, I could not measure innovation using "innovation input", but existing literature (e.g., Midrigan and Xu (2014)) suggests that intangible assets are related to

Table D.6: Import Intensity and Innovation: Leaders Are Top 1 Percent

	Initial Period		End Period		End Period before 2008	
	Leader	Follower	Leader	Follower	Leader	Follower
Panel A1: Standardized Patent Citations						
$\Delta \text{IMO}_{t-5,t}$	-0.001***	0.009	-0.005***	0.000***	-0.002***	-0.002
	(0.000)	(0.014)	(0.000)	(0.000)	(0.000)	(0.009)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.94	.7	.97	.82	.99	.89
Panel B1: Standardized Number of Patents						
$\Delta \text{IMO}_{t-5,t}$	-0.002***	0.009	-0.008	0.001***	-0.061*	0.001
	(0.001)	(0.019)	(0.023)	(0.000)	(0.032)	(0.000)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.97	.8	.62	.56	.94	.86
Panel C1: Standardized Citations of Radical Patents						
$\Delta \text{IMO}_{t-5,t}$	-0.057***	-0.008**	-0.405***	0.002	-1.967***	-0.035***
	(0.001)	(0.003)	(0.016)	(0.001)	(0.040)	(0.007)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.48	.69	.68	.58	.72	.56
Panel D1: Standardized Number of Radial Patents						
$\Delta \text{IMO}_{t-5,t}$	-0.099***	-0.002***	-0.005	-0.000	-0.007***	0.023
	(0.017)	(0.000)	(0.011)	(0.000)	(0.000)	(0.021)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.9	.89	.88	.41	.98	.68
Panel E1: Have Intangibles Or Not						
$\Delta \text{IMO}_{t-5,t}$	-0.003***	-0.000	-0.000	0.000**	-0.002***	-0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Obs.	115942	9020110	134262	9131985	43390	3205704
Adjusted R^2	.75	.71	.72	.74	.84	.84
Panel A2: Standardized Patent Citations						
$\Delta \text{IMO\_IV}_{t-5,t}$	-0.426***	0.061***	-0.080***	-0.002***	-0.580***	0.005***
	(0.062)	(0.001)	(0.020)	(0.000)	(0.076)	(0.001)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.94	.7	.97	.82	.99	.89
Panel B2: Standardized Number of Patents						
$\Delta \text{IMO\_IV}_{t-5,t}$	-0.858***	0.096***	-0.220**	-0.013***	-2.464***	0.007***
	(0.084)	(0.002)	(0.094)	(0.001)	(0.271)	(0.001)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.97	.8	.62	.56	.94	.86
Panel C2: Standardized Citations of Radical Patents						
$\Delta \text{IMO\_IV}_{t-5,t}$	-0.315***	-0.009	-0.734***	-0.012***	-8.493***	-0.050
	(0.013)	(0.271)	(0.066)	(0.004)	(0.395)	(0.032)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.48	.69	.66	.58	.62	.56
Panel D2: Standardized Number of Radial Patents						
$\Delta \text{IMO\_IV}_{t-5,t}$	-0.586***	0.026***	-0.142***	-0.005***	-3.527***	-0.010***
	(0.073)	(0.001)	(0.044)	(0.001)	(0.182)	(0.002)
Obs.	118719	9710908	137854	1.01e+07	44632	3513820
Adjusted R^2	.9	.89	.88	.41	.98	.68
Panel E2: Have Intangibles Or Not						
$\Delta \text{IMO\_IV}_{t-5,t}$	-0.019***	0.006	-0.021***	-0.001***	-0.016*	-0.006***
	(0.001)	(0.006)	(0.002)	(0.000)	(0.009)	(0.002)
Obs.	115942	9020110	134262	9131985	43390	3205704
Adjusted R^2	.75	.71	.72	.74	.84	.84

Notes: This table presents regression results of firm innovation measures from year $t-5$ to t against changes in import intensity from year $t-5$ to t in the data. Import intensity is measured in two ways: a country's own import-to-output ratio (Panel A1 to Panel E1) and other countries' import-to-output ratio (Panel A2 to Panel E2) at the industry level. The period is divided into an initial period before 2005, an end period since 2005, and an end period before 2008 (years between 2005 and 2007). The regressions include controls and fixed effects: industry-level import intensity and firm innovation measures at year $t-5$, country-year fixed effects, and firm fixed effects. The regression is weighted by firm sales and industry output. * $p < 0.10$, ** $p < 0.05$,*** $p < 0.01$.

innovation input. The "radical patents" measures address concerns that only innovations with a significant number of citations are relevant for TFP growth (Figures E.9, E.10, E.11, and E.12). (iv) **Sales growth in all industries**: I analyze how one-year sales growth rate of leaders and followers from all industries vary with measured technology gaps, addressing the potential issue that not all

Table D.7: Export Openness and Innovation Response

	Data (ΔPatent Citations$_{t-5,t}$)				Model (ΔInnovation Rate$_{t-5,t}$)			
	Initial Period		End Period		Initial Period		End Period	
	Leader	Follower	Leader	Follower	Leader	Follower	Leader	Follower
ΔEXO$_{t-5,t}$	1.700***	0.047***	-8.089***	-0.019***	11.352	-1.233	-18.463	-0.056
	(0.234)	(0.005)	(0.404)	(0.004)				
Obs.	118,719	9,710,908	137,854	1.01e+07				
Adjusted R^2	.94	.7	.97	.82	.53	.38	.62	.37
FEs and controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents regression results of firms' innovation responses from year $t-5$ to t to a change in export intensity from year $t-5$ to t in the data and in the model simulated 20-year transition dynamics. The initial periods denote years before 2005 in the data and the first 10 years in the model. The end periods denote years after 2005 in the data and the last 10 years in the model. The innovation measures are the standardized patent citations in the data and standardized innovation rate in the model. Fixed effects include country-year fixed effects and firm fixed effects. Controls include industry-level export intensity and firm-level innovation measures at year $t-5$. * $p < 0.10$, ** $p < 0.05$,*** $p < 0.01$.

firms depend on patents for growth (Figure E.6). The results are in line with the baseline findings. Similar patterns are observed when considering three-year and five-year sales growth, or estimated TFP growth. Due to better data coverage and a positive correlation, I report sales growth results rather than TFP growth. (v) **Alternative measures of technology gaps**: I use cumulative patent citations or the number of patents held by the firm (i.e., patent stock) to measure the technology gap. Since my focus is on a subset of countries worldwide, it is challenging to construct a proper measure of the global technology gap. Therefore, I only examine the robustness of the findings for the domestic technology gap and find consistent results. (vi) **Alternative sampling**: I first drop firms that are never observed applying for patents to address concerns that many small firms do not innovate, so including these firms would underestimate follower innovation. Dropping these non-innovative firms, which could leaders or followers, slightly weakens the pattern where most firms are concentrated in the decreasing part of the "inverted-U" in the domestic market. This suggests that as the domestic technology gap increases, a larger fraction of both leaders and followers become non-innovative. Second, I include only public firms for European countries to understand whether the U.S.-Europe differences are driven by the distinction between public and private firms. The results align with the baseline findings.[56] More results are available upon request.

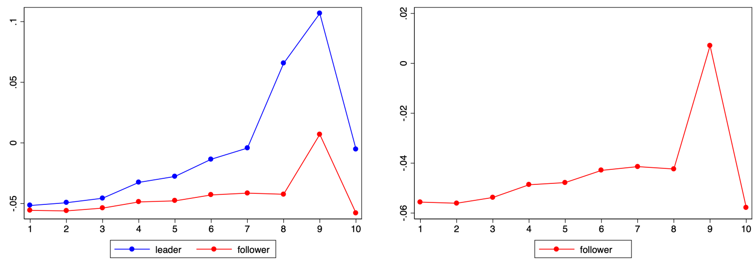
Figure E.3 shows standardized number of patent citations by technology gaps in the U.S. over time.[57] It shows they are predominantly concentrated on the decreasing part of the "inverted-U" in the domestic market. In the global market, an "inverted-U" shape is observed during early periods, while mainly the increasing part is seen during late periods. This suggests that in the U.S., innovation among leaders and followers initially increases and then slightly decreases with the global technology gap. However, later, most leaders and followers' innovation consistently increases with the global technology gap. The global market results may imply that the U.S. is more technologically advanced than Europe, with dominant U.S. leaders in the decreasing part of the "inverted-U." Yet, the U.S. appears to be losing its global technological advantage, causing most firms to shift to the increasing part of the "inverted-U" over time. However, since the U.S. data only covers public firms with consolidated accounts, I consider these findings as supplementary rather

[56]Note that in these two exercises, the classification of leaders and followers remains unchanged, but only patenting firms or public firms are used to construct the empirical facts. In my sample, 99 percent of European firms are private firms, while almost all U.S. firms are public firms.

[57]The U.S. has longer data series than European countries, so I use years 1995-2000 to denote early periods to be more consistent with the classification in existing literature. I use the U.S. data from 1995 since the industry output data from OECD input-output table starts from 1995.

than the main focus of the paper.

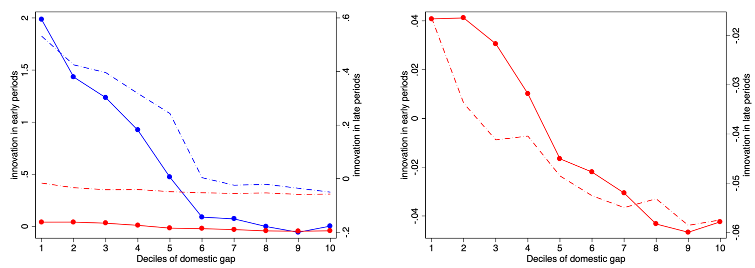
Figure E.2: Standardized Number Of Patent Citations: All Firms, Old Periods



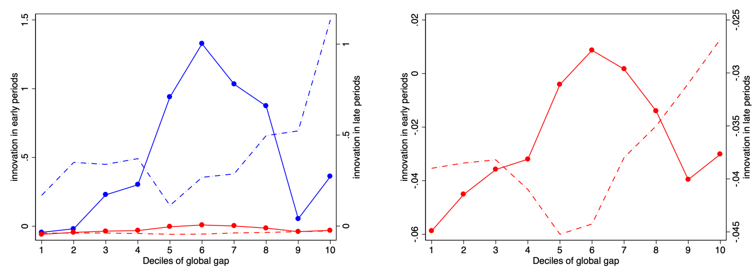
(a) US: leader over domestic gap (b) US: follower over domestic gap

Notes: The X-axis in each panel denotes the deciles of measured domestic technology gaps. The Y-axis denotes the standardized number of citations of all firms. The data covers the data from 1970 to 1994.

Figure E.3: Standardized Number of Patent Citations By Technology Gap: All U.S. Firms



(a) leader over domestic gap (b) follower over domestic gap



(c) leader over global gap (d) follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of citations of all firms. The blue (red) line represents leaders (followers). The solid (dashed) line represents the early (late) period.

E.2.2 Smaller Firms Have Higher Innovation Intensity

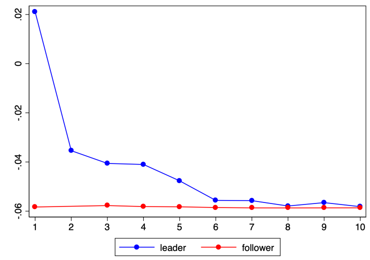
I demonstrate that my data can replicate several existing empirical facts on firm innovation. Specifically, I show that within an industry, smaller firms tend to apply for fewer patents and receive fewer patent citations. However, they have a higher innovation intensity, as measured by the number of patents and citations relative to sales. Additionally, when smaller firms do apply for patents, a larger fraction of these patents are classified as radical.

The empirical specification is as follows: for firm i in industry j, country c, and year t,

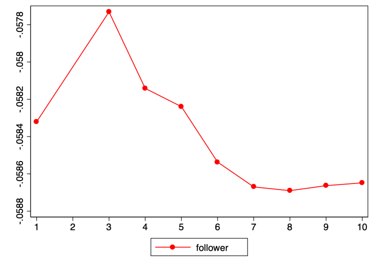
$$y_{i,j,c,t} = \beta_0 + \beta_1 \ln(sale_{i,j,c,t}) + \alpha_{j,t} + \gamma_{c,t} + \delta_i + \epsilon_{i,j,c,t}, \tag{E.1}$$

where $y_{i,j,c,t}$ denotes number of patents ($\mathrm{N}_{\mathrm{Patents}}$), number of patent citations ($\mathrm{N}_{\mathrm{Citations}}$), number

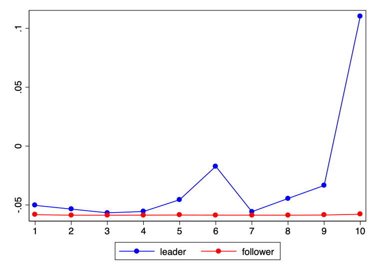
Figure E.4: Standardized Number Of Patent Citations By Technology Gap: All Firms, Late Periods Before Financial Crisis



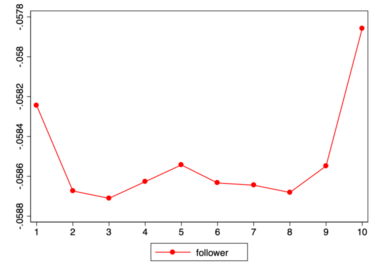
(a) Europe: leader over domestic gap



(b) Europe: follower over domestic gap



(c) Europe: leader over global gap



(d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of citations of all firms.

of patents-to-sales ratio ($\frac{\text{Patents}}{\text{Sales}}$), number of patent citations-to-sales ratio ($\frac{\text{Citations}}{\text{Sales}}$), and fraction of patents that are radical patents among all patents that the firm applied for in year t ($\text{Frac}_{\text{Radical}}$). $\ln(\text{sale}_{i,j,c,t})$ denotes the natural logarithm of sales, $\alpha_{j,t}$, $\gamma_{c,t}$, and δ_i represent industry-year fixed effects, country-year fixed effects, and firm fixed effects.

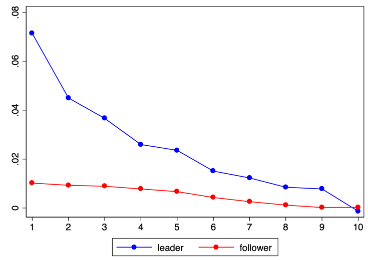
Tables E.1 shows the results with two different samples: all firm-year observations and firm-year observations with patents. The latter sample is to highlight how, conditional on firms applying for a patent, firm size matters for innovation intensity and the nature of patenting (radical or not).

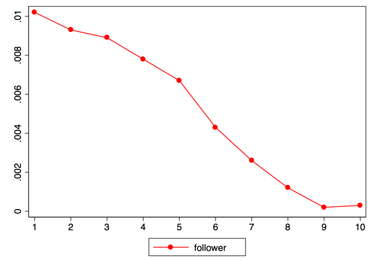
Table E.1: Smaller Firms Have Higher Innovation Intensity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	All Firm-year Observations					Firm-year Observations with Patents				
	N_{Patents}	$N_{\text{Citations}}$	$\frac{\text{Patents}}{\text{Sales}}$	$\frac{\text{Citations}}{\text{Sales}}$	$\text{Frac}_{\text{Radical}}$	N_{Patents}	$N_{\text{Citations}}$	$\frac{\text{Patents}}{\text{Sales}}$	$\frac{\text{Citations}}{\text{Sales}}$	$\text{Frac}_{\text{Radical}}$
Europe										
ln(sale)	0.002***	0.017***	-0.000***	-0.000***	-0.000***	1.039***	25.837***	-0.285***	-0.965***	-0.008***
	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	(0.350)	(3.793)	(0.016)	(0.150)	(0.002)
Obs.	4.96e+07	4.96e+07	4.96e+07	4.96e+07	4.96e+07	37213	37213	37213	37213	37213
Adjusted R^2	.68	.65	-.088	.27	.11	.64	.61	-.25	.32	.33
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
U.S.										
ln(sale)	1.319***	45.701***	-0.003***	-0.001***	0.000	6.149***	299.196***	-0.017***	-8.841***	-0.013***
	(0.333)	(6.366)	(0.000)	(0.000)	(0.001)	(1.882)	(35.785)	(0.002)	(0.487)	(0.002)
Obs.	121211	121211	121211	121211	121211	24778	24778	24778	24778	24778
Adjusted R^2	.63	.7	.0098	.12	.44	.61	.69	-.052	.47	.55
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

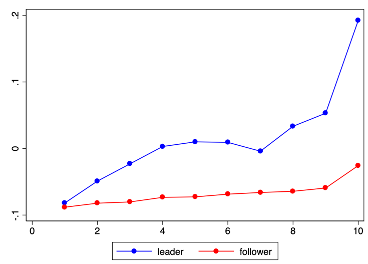
Notes: This table presents results from estimating equation (E.1) for European and U.S. firms. Fixed effects include industry-year fixed effects, country-year fixed effects, and firm fixed effects. The regression is weighted by firm sales. Firm sales are in thousands of U.S. dollars. The definition of variables of interest is in section 2.1 and Appendix F. * $p < 0.10$, ** $p < 0.05$,*** $p < 0.01$.

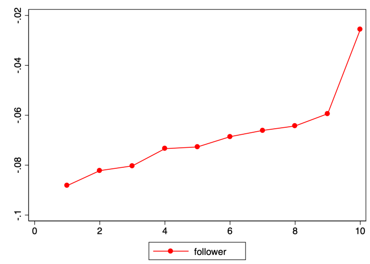
Figure E.5: Standardized Number Of Patent Citations By Technology Gap: All Firms, Early Period, Controlling for Fixed Effects





(a) Europe: leader over domestic gap (b) Europe: follower over domestic gap

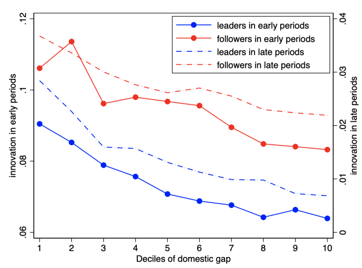


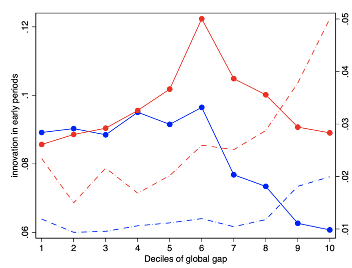


(c) Europe: leader over global gap (d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of citations of all firms after controlling for country-year FE, firm FE, and firm-level characteristics (leverage, total assets). Leverage is computed as the total debt-to-total assets ratio.

Figure E.6: Sales Growth Rate By Technology Gap: All Firms, Early and Late Period





(a) over domestic gap (b) over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the sales growth rate of all firms in all industries in early and late periods in European countries.

F Firm-Level Data

F.1 Data Cleaning Procedure

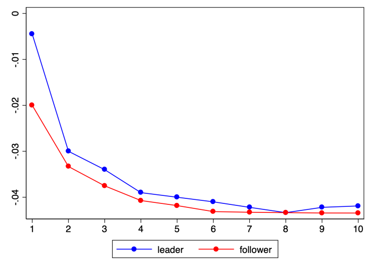
I first clean the balance sheet data and intellectual property data separately, and then merge the two together via the unique firm ID, BvD ID. The detailed steps are listed below.

Step 1. Clean firm financial balance sheet information from ORBIS historical data.

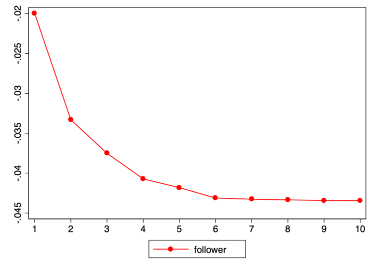
(1) Delete observations with a missing BvD ID or BvD account number and observations with just a company name and no other information.

(2) Assign the calendar year using the variable "Account Closing Date" CLOSEDATE. Following Kalemli-Ozcan et al. (2022), if the closing date is after or on June 1st, the current year is

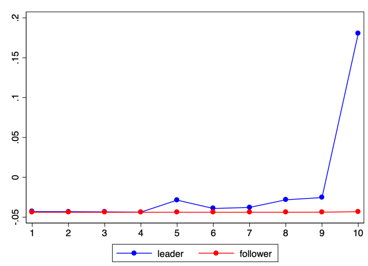
Figure E.7: Standardized Number Of Patent Citations By Technology Gap: All Firms, Early Period, Leaders are Top 1



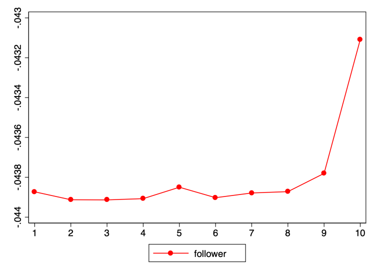
(a) Europe: leader over domestic gap



(b) Europe: follower over domestic gap



(c) Europe: leader over global gap



(d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of citations of all firms.

assigned (if CLOSEDATE is the 4th of August, 2003, the year is 2003). Otherwise, the previous year is assigned. Drop observations with missing year information.

(3) Drop firm-year observations with duplicates or missing information regarding their industry of activity or consolidation code.

(4) Drop firm-year observations with missing or negative operating revenue, total assets, fixed assets, or costs of employees.

(5) Construct the variable “age” of the firm as the difference between the balance sheet year and the year of incorporation plus one. Drop firms with non-positive age values.

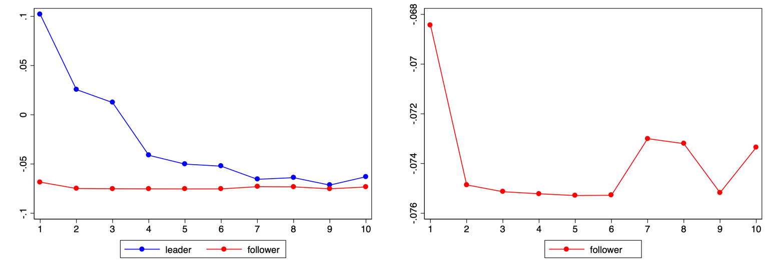
(6) Keep unconsolidated accounts only for European countries but keep consolidated accounts only for the U.S. firms. Keep only years of interest: from 1999 to 2015. Keep all non-government non-financial industries.

Step 2. Clean the patent data from ORBIS Intellectual Property. Define the year of the patent by application filing date. Identify the technology class of the patent by IPC code. Drop observations with missing applicant IDs, application filing dates, publication number, or IPC codes.

Step 3. Merge patent data with firm balance sheet data via BvD ID, and count only patents that can be matched with a firm balance sheet.[58]

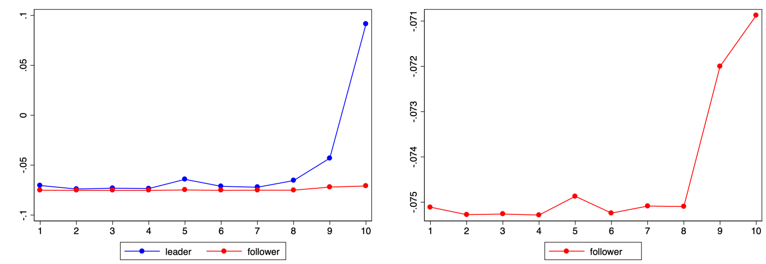
[58] In the baseline analysis, I use firm sales to construct technology gaps and document how firm innovation varies with the technology gaps. In a robustness check, I use patent stock to construct technology gaps and consider all patents instead of patents that can be linked to balance sheets to document related empirical facts. Results are similar.

Figure E.8: Standardized Number Of Patent Citations By Technology Gap: All Firms, Early Period, Leaders Are Top 5 Percent



(a) Europe: leader over domestic gap

(b) Europe: follower over domestic gap

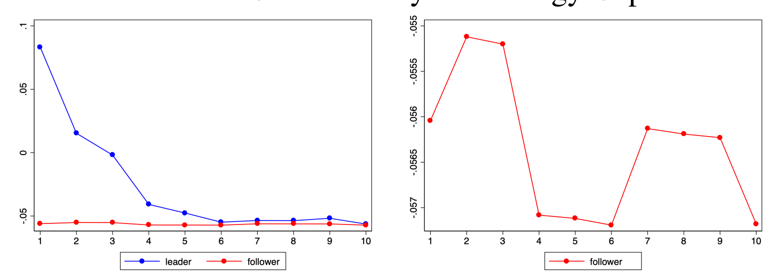


(c) Europe: leader over global gap

(d) Europe: follower over global gap

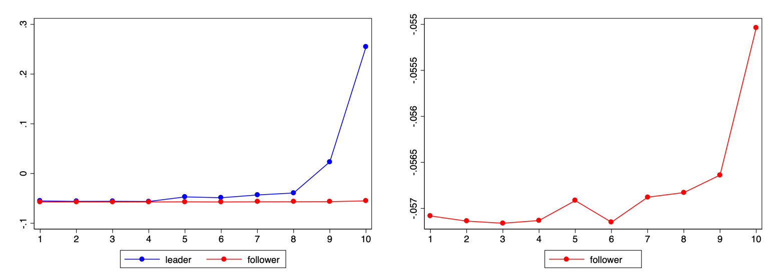
Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of citations of all firms.

Figure E.9: Standardized Number Of Patents By Technology Gap: All Firms, Early Period



(a) Europe: leader over domestic gap

(b) Europe: follower over domestic gap

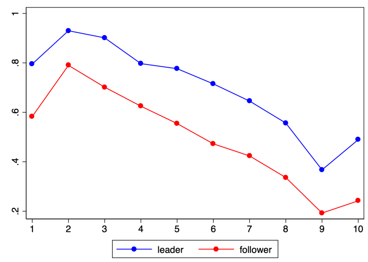


(c) Europe: leader over global gap

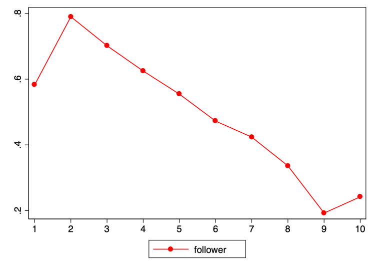
(d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of patents of all firms.

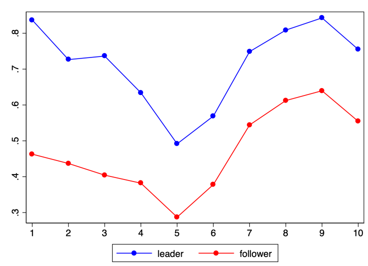
Figure E.10: Share of Firms With Intangible Assets By Technology Gap: All Firms, Early Period



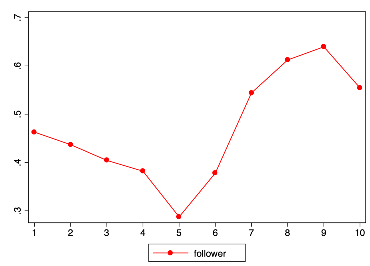
(a) Europe: leader over domestic gap



(b) Europe: follower over domestic gap



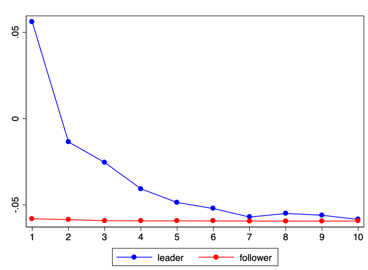
(c) Europe: leader over global gap



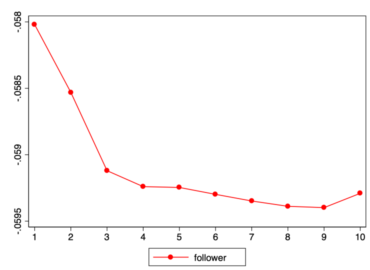
(d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the fraction of firms that have intangible assets.

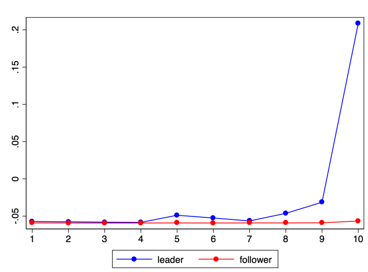
Figure E.11: Standardized Number Of Radical Patents By Technology Gap: All Firms, Early Period



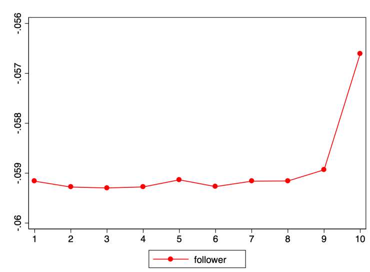
(a) Europe: leader over domestic gap



(b) Europe: follower over domestic gap



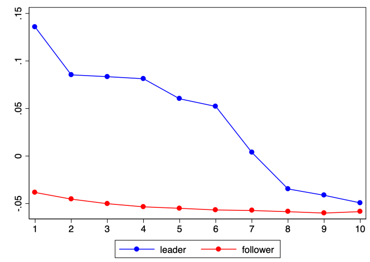
(c) Europe: leader over global gap



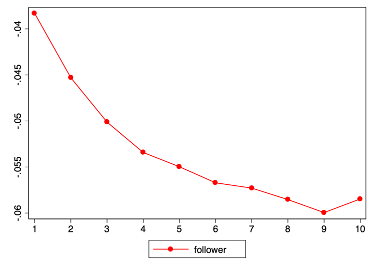
(d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized number of radical patents of all firms.

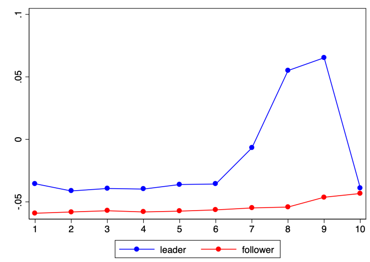
Figure E.12: Standardized Citations Of Radical Patents By Technology Gap: All Firms, Early Period



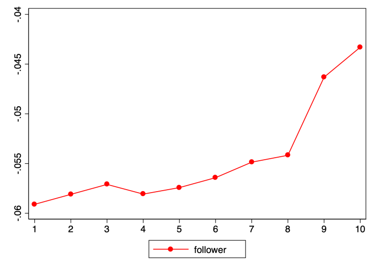
(a) Europe: leader over domestic gap



(b) Europe: follower over domestic gap



(c) Europe: leader over global gap



(d) Europe: follower over global gap

Notes: The X-axis in each panel denotes the deciles of measured domestic or global technology gaps. The Y-axis denotes the standardized citations of radical patents of all firms.

F.2 Variable Construction

Innovation Output and Input. Firm i's total patents in year t is the total number of granted patents p applied for in year t and the number of citations some patent p received from year t onwards is citation_{pt}. I define the number of patent citations for the firm in year t as $\sum_p \text{citation}_{pt}$, and the number of citations in year $t' = \sum_{p'} \text{citation}_{p't'}$, where $p' \neq p, t' \neq t$. I then compute the number of citations per patent by firm. Note that patent citations are adjusted by the truncation correction weights developed by Hall et al. (2001). I define a patent as a *radical patent* if its citations are above the 75th percentile among all patents. I then use the number of radical patents and citations of radical patents as alternative innovation measures. To ensure the robustness of the empirical findings, I also use alternative thresholds, such as the 99th or the 90th percentile. *Intangible intensity* is computed as the fraction of intangible fixed assets as a share of total fixed assets (total fixed assets = intangible fixed assets + tangible fixed assets + other fixed assets). Intangible fixed assets include formation expenses, research expenses, goodwill, development expenses and all other expenses with a long term effect.

Firm Size, Firm-Level Export Intensity, and Leverage. I measure sales by operating revenue to maximize data coverage.[59] When measuring sales, I use the unconsolidated accounts of firms to identify their operating industry and isolate the contribution of foreign subsidiaries to focus on domestic activities. When using the consolidated accounts, the foreign subsidiaries of a firm are bundled together with its domestic operations. Further, I consider exports instead of multinational production as foreign sales because the data coverage of multinational production in ORBIS is

[59] I rechecked empirical facts using sales and found similar results.

sufficient only since 2007, which is inadequate for examining the secular trends occurring since the 1990s. Regrettably, the U.S. only covers firms in consolidated accounts that include multinational production. Therefore, I exclude the U.S. when computing domestic concentration.

Exports is obtained from the variable "export revenue", and only France and Greece have good coverage on exports. I measure domestic sales as the difference between sales and exports.[60] Firm-level export intensity is defined as the exports-sales ratio of the firm. Due to limitations in the firm-level export and import data available in ORBIS, I mainly utilize industry-level data to construct measures of export and import intensity for documenting facts, as detailed in main text. Leverage is computed as the total debt-to-total assets ratio.

F.3 Data Representativeness

Panel A in Table F.1 presents the fraction of gross output (operating revenue) accounted for by firms belonging to each size class in separate countries in 2006. The size distribution calculation includes firms from all industries, in line with the construction of Table 2 in Kalemli-Ozcan et al. (2022). The results are consistent with the firm size distribution in Kalemli-Ozcan et al. (2022), which is consistent with the official data on size class provided by Eurostat.

Table F.1: Firm Size Distribution in Terms of Gross Output: 2006

Country Code	DE	DK	ES	FI	FR	GB	GR	IT	NL	NO	PT	SE	US
Panel A. This Paper													
1 to 19 employees	0.15	0.14	0.24	0.23	0.14	0.07	0.21	0.21	0.23	0.29	0.30	0.26	0.00
20 to 249 employees	0.26	0.40	0.39	0.37	0.32	0.26	0.49	0.43	0.44	0.41	0.38	0.30	0.01
250+ employees	0.59	0.46	0.37	0.40	0.53	0.68	0.30	0.36	0.33	0.30	0.32	0.44	0.99
Panel B. Table 2 from Kalemli-Ozcan et al. (2022)													
1 to 19 employees	0.16	0.15	0.26	0.24	0.15	0.07	0.22	0.21	0.22	0.29	0.31	0.26	
20 to 249 employees	0.26	0.42	0.39	0.37	0.33	0.27	0.5	0.44	0.46	0.39	0.38	0.32	
250+ employees	0.58	0.43	0.35	0.39	0.52	0.66	0.28	0.35	0.33	0.32	0.31	0.42	

Notes: Panel A presents the fraction of gross output (operating revenue) accounted for by firms belonging to each size class in separate countries in 2006. The size distribution calculation includes firms from all industries, in line with the construction of Table 2 in Kalemli-Ozcan et al. (2022).The country codes are DE (Germany), DK (Denmark), ES (Spain), FI (Finland), FR (France), GB (United Kingdom), GR (Greece), IT (Italy), NL (Netherlands), NO (Norway), PT (Portugal), SE (Sweden), and US (United States).

G Industry-Level TFP Construction

To the best of my knowledge, the only publicly available data set that provides detailed 2-digit industry TFP information across countries from the 1990s to now is EU KLEMS, however, this data set only provides TFP growth, not TFP level.[61] To this end, I utilize the labor input, capital input, and value added in this data set to construct industry TFP that is comparable across countries.[62]

Methodology. I use the multilateral TFP index, which has been widely adopted by existing literature (see, e.g., Keller (2002), Cameron et al. (2005), Inklaar and Timmer (2008)). For industry j in country c and year t, consider $\ln(\frac{Z_{cjt}}{Z_{Fjt}}) = \ln(\frac{Y_{cjt}}{Y_{Fjt}}) - \bar{\alpha}_{cjt}\ln(\frac{L_{cjt}}{L_{Fjt}}) - (1-\bar{\alpha}_{cjt})\ln(\frac{K_{cjt}}{K_{Fjt}})$, where $\bar{\alpha}_{cjt} = \frac{\alpha_{cjt}+\alpha_{Fjt}}{2}$. Z is TFP, Y is value added, L is labor input, and K is capital input. The country

[60]The data shows more than 99.99% of firms in France and Greece have positive domestic sales. Therefore, most exporters sell in the domestic market.

[61]Relatedly, Inklaar and Timmer (2008) only provides data in 1987, 1997 and 2005.

[62]Note that EU KLEMS 2019 only provides data for all European Union member states, Japan, and the US. Therefore, some countries that are covered in OECD input-output tables are not covered in EU KLEMS. The classifications of OECD and ROW countries are the same as in section 4.2.

F represents the reference country, i.e., the U.S. in this case. The variable $\bar{\alpha}_{cjt}$ is the average labor share in industry j between the U.S. and country c. Normalizing the U.S. TFP level to 1 in all industries, the TFP level in other countries can be pinned down. These index number measures of TFP are consistent with a translog production technology, which provides an arbitrarily close local approximation to any underlying constant returns to scale production technology, and are more general than those commonly derived from the Cobb–Douglas production function.

Practical implementation. To ensure the measured TFP reflects productivity differences across countries instead of price differences, a common practice is to use aggregate economy purchasing power parity (PPP) exchange rates to convert value-added and factor inputs into common currency units. To this end, I use aggregate economy PPP data from the OECD (USA $\equiv$ 1) to convert value-added and factor inputs in EU KLEMS (in national currency) into common currency units. The labor input is measured by compensation of employees. Compared to hours worked or number of employees, the benefit of using compensation of employees is that it captures country-industry variation in the skill composition of the workforce. The capital input is measured by the capital stock adjusted for cyclical differences in capacity utilization. Specifically, I regress the capital stock in the country-industry level annual panel on the U.S. capital utilization index (TCU in FRED), and keep the residual term as the capital input adjusted for cyclical differences in capacity utilization.

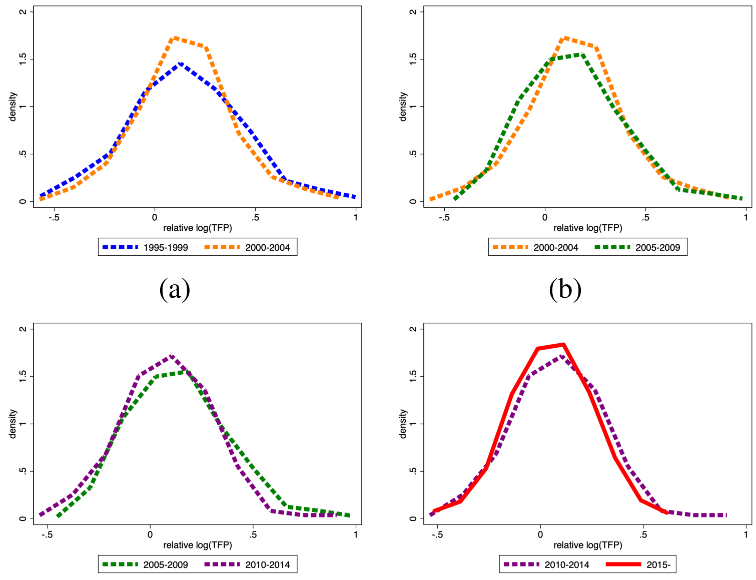
Controlling for alternative mechanisms. Besides considering capital utilization over the business cycle and labor quality differences across countries, I control for TFP improvements due to improving allocation or innovation subsidies. This paper shows increasing international knowledge spillovers lead to faster improvement in TFP in less developed countries. However, motivated by the misallocation literature (Hsieh and Klenow (2009)), this catch-up growth could be due to improving allocation of resources across heterogeneous firms over time instead of productivity increases, possibly driven by domestic reforms. Alternatively, national innovation subsidy policies could affect innovation investment and TFP growth. To control for these alternative stories, I regress measured TFP on a financial development index (directly obtained from the IMF), a labor quality improvement index (measured by expenditure on tertiary education as a share of government expenditure on education), and the ease of doing business index and the R&D-GDP ratio (directly obtained from the World Bank). I take the residual term from these regressions as a benchmark measure of TFP, which is used for the analysis in the main text.[63]

Distribution of relative TFP across industries. Figure G.1 presents the industry density distribution over relative productivity between OECD and ROW every five years, using the constructed TFP data. Relative productivity is the log difference in industry TFP between OECD and ROW. A relative productivity larger than 0 means OECD is more productive than ROW. A larger density concentrated in high relative productivity levels means more OECD industries have a technological advantage. As indicated by Figure G.1, the distribution in the 1990s is more concentrated in regions where OECD has a technological advantage over ROW, while over time this distribution gradually

[63]Recently the increasing innovativeness of China raises a concern that the decrease in relative TFP between OECD and ROW is not from increasing international knowledge spillovers but from increasing Chinese innovativeness due to government subsidies for innovation and possibly other reasons. However, three points are worth mentioning. First, the industry-level TFP data set I construct excludes China and is primarily European. Second, the existing literature agrees on substantial and increasing international knowledge spillovers from the OECD to China as detailed in section 1. Third, controlling for the R&D-GDP ratio when constructing TFP helps alleviate this concern.

shifts to the left and becomes more constrained.

Figure G.1: Industry Density Distribution Over Relative Productivity in the Data



(a) (b) (c) (d)

Notes: Panel (a) to (d) in this figure present snapshots of the industry density distribution over relative productivity between OECD and ROW every five years. The X-axis denotes the log difference in industry TFP between OECD and ROW. The Y-axis denotes industry density.

Three robustness tests. First, there is a concern that cross-country relative prices may vary substantially across industries, so using aggregate PPP could lead to a biased measure of TFP. I therefore use time-invariant industry-specific PPP data from Inklaar and Timmer (2014) to reconstruct TFP.[64] Second, there is a concern that a volatile labor share (share of labor in value-added) indicates potential measurement errors. I follow Harrigan (1997) in using the properties of the translog production technology to smooth the observed labor shares. Specifically, I regress the labor share on industry-country fixed effects and capital-labor ratios, and use the fixed effect part as representing the series without measurement errors. Third, I restrict the data sample to industries with positive trade to construct TFP, which encompasses both manufacturing and service trade. This addresses the concern that the relative productivity to be isolated should be influenced by international knowledge spillovers and tradable sectors could be more likely to be affected by these spillovers than non-tradable sectors. In all robustness tests, I find results are consistent with the benchmark results.

[64]The industry-specific data is time-invariant since the data is just for 2005.