

# International trade and innovation<sup>☆</sup>

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## Abstract

We provide a review of the recent literature – both theoretical and empirical – analyzing the multi-dimensional connections between globalization and innovation. We develop a model that features many of those mechanisms that connect trade and innovation. It features the joint selection of firms into innovation and international market participation (in our model, we restrict that participation to exports). Our model also highlights how exposure to international markets affects the incentives for innovation.

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**Keywords**

Trade, Innovation, R&amp;D, Competition, Spillover, Globalization

**1 Introduction**

Globalization and innovation are important forces shaping economic outcomes around the world, and they are deeply intertwined.<sup>1</sup> There is now overwhelming empirical evidence connecting various measures of innovation – be it R&D, patents, technology adoption, investment in product quality – with participation in international markets – whether via exposure to export markets or import competition, via participation in international supply chains (either as a buyer or supplier of intermediate goods), or via participation in a multinational firm network. For example, Foster et al. (2016) report that between 1990 and 2011, 50%-60% of the American firms with positive R&D perform some international transactions; while only 8% of firms with no reported R&D are engaged in international transactions. Similarly, Aghion et al. (2018) show that French manufacturing exports are dominated by a small proportion of patent-holding firms.<sup>2</sup> This evidence highlights causality links running in both directions. From firm or industry performance (including prior innovation outcomes) to participation in international markets as well as from changes in those markets – globalization – to innovation. In some cases, these links are generated by other variables that affect both innovation and globalization.<sup>3</sup>

In this chapter, we provide a review of the recent literature analyzing these connections between globalization and innovation, both theoretically and empirically. We develop a model that features many of those mechanisms that connect trade and innovation. It features the joint selection of firms into innovation and international market participation (in our model, we restrict that participation to exports). Our model also highlights how exposure to international markets affects the incentives for innovation. This includes the long-established positive market size effect on innovation as well as the impact of competition. As has been highlighted many times in the literature, the direction of this competition effect on innovation is ambiguous. It can be negative (business stealing) as well as positive (incentives to escape com-

<sup>1</sup> A recent IMF report has documented growing signs in many industries that market power is becoming entrenched amid an absence of strong competitors for dominant firms (Akcigit et al., 2021). Hence fostering international competition has become even more crucial to revitalize business dynamism and productivity growth around the world.

<sup>2</sup> See Altomonte et al. (2013) for a study of European firms looking across all those different modes of international market participation and innovation; and Shu and Steinwender (2019) for a recent survey of the empirical evidence.

<sup>3</sup> Consider the case of the pharmaceutical industry: Acemoglu and Linn (2004) provide evidence that exogenous domestic changes in demand induce innovation in drugs oriented to the growing groups; while in a subsequent study, Costinot et al. (2019) show that those same exogenous demand changes generate increases in the exports of those drugs around the world.

petition). It is therefore not surprising that the empirical evidence on this channel has found both positive and negative effects in different contexts (see section 4). Quantitative models have been used to assess the relative strength of these mechanisms in open economy settings. (See in particular Eaton and Kortum, 2001; Akcigit et al., 2018; Somale, 2021).

There is also a large literature analyzing a direct knowledge transfer or spillover associated with international market participation. In this literature, international markets matter because they directly affect the type or quality of technology that can be adopted. Some of these spillovers have been conceptualized as exchanges of ideas that take place when firms engage in international trade or multinational production.<sup>4</sup> In other cases, the exchange occurs with other domestic producers. International trade (globalization more generally) still matters because it affects the composition of those domestic firms. A different type of spillover has to do with changing prices as a consequence of globalization: it can improve the availability or quality of inputs available to firms, and hence their innovation incentives; or it can induce changes in relative factor prices thereby altering the direction of innovation in the context of directed innovation. In these situations, changes in comparative advantage shape the response of innovation to trade.<sup>5</sup>

Our theoretical model focuses on how international markets affect the *incentives* for endogenous innovation by incumbent firms. We model the outcome of successful innovation as increases in quality. Successful innovation could also lead to new products that do not entirely displace existing ones and hence increases in product variety.<sup>6</sup> Although the exact sources of the induced welfare gains are different, the main concept of successful innovation – as a shift in technology that allows an incumbent firm to produce a bundle of goods yielding higher utility with given inputs – remains. Endogenous entry whereby a prospective firm pays a fixed (potentially sunk) cost to develop a new set of products also generates a similar shift in the technological frontier, although at the *industry* level. Indeed, many models associate such increases in product variety as the outcome of successful product innovation. We will discuss the parallels and differences between models where innovation is driven by entrants as opposed to incumbent firms. And we then separately discuss the case of knowledge spillovers, where international markets directly affect the innovation process – instead of indirectly via the incentives for innovation. Although these two channels are distinct, both of those tend to generate similar predictions linking trade to growth.

<sup>4</sup> See Keller (2010) for a recent survey of the literature on technology transfers with an emphasis on the connections to FDI.

<sup>5</sup> See Grossman and Helpman (1991a), Grossman and Helpman (1995), and Melitz and Redding (2021) for reviews of this literature.

<sup>6</sup> See Dhingra (2013) for a model of innovation where incumbent firms can both increase the efficiency of existing products as well as introduce additional products.

The rest of the chapter is organized as follows. Section 2 discusses recurrent data and measurement issues. Section 3 develops our theoretical framework that highlights the main channels connecting trade and innovation; and section 4 discusses some additional empirical evidence related to those channels. Section 5 reviews the literature on international technology diffusion and knowledge spillovers. And Section 6 concludes.

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## 2 Measurement issues

Most of the empirical studies we review in Section 4 measure innovation using either data on inputs (R&D) or outputs (patents, self-reported innovation). A different strand of the literature has studied productivity more broadly. Ultimately, the impact of innovation will show up in productivity – assuming that output is deflated with the appropriate welfare-relevant price index (which would then capture increases in product variety and quality). But productivity gains can also be the outcome of processes that do not involve innovation. Even when productivity gains are the direct result of innovation, that transfer from one to the other unfolds slowly over time, making it hard to evaluate the innovation outcomes using productivity.<sup>7</sup> For these reasons, we focus on the literature relying on innovation outcomes.<sup>8</sup>

Some aspects of international patenting activity need to be taken into account when using patents as an outcome variable in this setting. First, multinational firms are the main actors in international trade (OECD (2018)). If these firms carry out their R&D activities in a different country than the one in which production takes place, the link between innovation and globalization maybe missed.<sup>9</sup> Aghion et al. (2018) and Coelli et al. (2022) deal with this explicitly by focusing on primary patents only.<sup>10</sup> Most of the studies, however, focus on domestic patents.

A second concern is that, due to research lead time, innovation should react with some (unknown) lag to changes in incentives. There have been two ways of dealing with this. Papers estimating general equilibrium models, such as Akcigit et al. (2018) and Cai et al. (2022), deal with this explicitly by postulating a research production function whose elasticities are estimated. Some studies focusing on reduced-form estimates (Acemoglu and Linn (2004), Chakravorty et al. (2017), Aghion et al. (2018)) check the effects on lagged, current, and lead changes in incentives to innovate.

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<sup>7</sup> See Bilir and Morales (2020) and Doraszelski and Jaumandreu (2013) for examples of papers measuring this transfer at the firm-level.

<sup>8</sup> See Shu and Steinwender (2019) for a survey of the broader empirical literature linking trade and productivity.

<sup>9</sup> Bilir and Morales (2020) find that 20% of the return to R&D in multinational firms is realized abroad, and Arkolakis et al. (2018) find that specialization in innovation at the national level can be important.

<sup>10</sup> Primary patents refer to the first time an innovation is patented.

### 3 Theoretical channels

We now develop a theoretical framework – strongly inspired by Akcigit and Kerr (2018) – that features the key selection, market size, and competition effects that shape the connections between trade and innovation. In this model, the key international market participation decision driving selection involves a single export market destination. Competition can take the form of entry either by additional domestic producers or by foreign sellers (import competition).

Our model is a quality-ladder model as in Aghion and Howitt (1992) and Grossman and Helpman (1991a). We focus on the innovation incentives for *incumbent* firms, assuming exogenous entry; whereas in those other models incumbents do not innovate and entry is the outcome of successful innovation by prospective entrants. In all those cases, the outcome of successful innovation is to achieve a technology one-step ahead of the current technology in use. Thus, innovation decisions by the incumbents in our model are very similar to those made by entrants in those other models. One key difference between innovation by entrants and incumbents is that incumbents currently earn positive profits whereas entrants do not earn any profits. This “Arrow” replacement effect implies that entrants have a higher incentive to innovate than incumbents; and when the innovation cost is linear in effort (as is the case in those models), then incumbents do not perform any innovation. In our model, we explore this “Arrow” replacement effect when we consider competition *between* incumbent firms that operate with convex innovation costs. This lets us consider the impact of endogenous changes in competition on innovation incentives. In particular, this allows us to separately examine the channels of import competition from exposure to export markets. Although we develop an extension with endogenous entry, we show that our model with exogenous entry captures the main selection, market size, and competition channels highlighted by the theoretical literature. As we previously mentioned, our model focuses on the links between trade and the *incentives* for endogenous innovation. We discuss later how the predictions of this model match up with the literature on knowledge spillovers where trade impacts the innovation process itself – typically in models where the innovation decision is exogenous.

We begin with a model specification where the firms’ innovation decision is myopic (only incorporating profits one period ahead) – as this simplified structure still captures all those key channels. We then show how this framework can be extended into one where firms make “fully dynamic” decisions. We highlight some variations of this model that lead to particularly simple and tractable versions – including analytical closed-form representations for the firm value function.

#### 3.1 Basic environment

Consider the following closed-economy model. The final good  $Y_t$  is produced in a perfectly competitive market using labor and an exogenous set  $N$  of intermediate

goods (indexed by  $j$ ) according to the production function<sup>11</sup>

$$Y_t = \frac{L^\beta}{1-\beta} \int_0^N q_{jt}^\beta k_{jt}^{1-\beta} dj, \quad (1)$$

where  $k_{jt}$  is the quantity of intermediate good  $j$  at time  $t$ ,  $q_{jt}$  represents its quality, and aggregate labor  $L$  is inelastically supplied and pins down market size. We normalize the price of the final good to 1 without loss of generality.  $\beta \in (0, 1)$  plays a dual role as the share of the fixed factor in production and the inverse elasticity of substitution between the intermediate varieties  $j$ . We choose this for simplicity as we do not undertake any comparative statics in this parameter. All our results would remain unchanged if we assigned two different variables to those separate concepts. Similarly, the choice of  $\beta$  involves a specific normalization for the units of quality, again without loss of generality. We drop the time index when it causes no confusion.

The maximization problem of the final good producer is expressed as

$$\max_{L, k_j} \left\{ \frac{L^\beta}{1-\beta} \int_0^N q_j^\beta k_j^{1-\beta} dj - p_j k_j - Lw \right\}. \quad (2)$$

The resulting first order conditions imply that the demand for the fixed factor and intermediate good  $j$  are:

$$\begin{aligned} w &= \frac{\beta}{1-\beta} L^{\beta-1} \int_0^N q_j^\beta k_j^{1-\beta} dj, \\ p_j &= L^\beta q_j^\beta k_j^{-\beta}. \end{aligned} \quad (3)$$

Each variety  $j$  is produced by a monopolist at a constant marginal cost  $\eta > 0$  using only its own intermediate input. Therefore, the profit maximization problem for each monopolist  $j$  can be expressed as:

$$\pi_j = \max_{p_j, k_j} \{ p_j k_j - \eta k_j \} \quad \text{subject to (3),}$$

and leads to the equilibrium quantity and price:

$$\begin{aligned} k_j &= \left[ \frac{1-\beta}{\eta} \right]^{\frac{1}{\beta}} L q_j, \\ p_j &= \frac{\eta}{(1-\beta)}. \end{aligned} \quad (4)$$

<sup>11</sup> We develop an extension with endogenous entry leading to an endogenous set  $N$  of intermediates in a later section.

Substituting those in (5) indicates that profit is proportional to quality:

$$\pi_j = \Upsilon L q_j, \quad \Upsilon \equiv \left( \frac{1-\beta}{\eta} \right)^{\frac{1-\beta}{\beta}} \beta. \quad (5)$$

### 3.2 Innovation decision with myopic firms

We now characterize innovation incentives, which are the only forward-looking part of firm behavior in our model. To simplify the exposition, we first assume that firms are myopic and maximize instantaneous (one-step ahead profits) in a discrete-time setting, rather than the discounted sum of those profits. This enables us to provide analytical expressions for R&D decisions in a wide range of scenarios, clarifying the basic economic forces. We will then turn to forward-looking maximization by firms in a continuous-time setting and show that the same intuitions carry over; with the exception that the latter will require us to solve the firm's dynamic Hamilton-Jacobi-Bellman equation.

The innovation outcome for intermediate good producers is stochastic. If successful, the firm's quality increases by a step  $\lambda > 0$  from  $q_j$  to  $(1 + \lambda)q_j$  the following period. If unsuccessful, the firm's quality remains unchanged at  $q_j$ . The firm's endogenous innovation effort affects the probability  $x_j$  of successful innovation. For simplicity and to ensure an interior solution for the firm's innovation choice  $x_j$ , we assume an innovation cost function  $\theta q_j x_j^2$  where  $\theta > 0$  is large enough that all firms choose  $x_j < 1$ .<sup>12</sup> This cost function is linear in the firm's quality  $q_j$ . In the dynamic growth setting that we consider later, this will ensure that growth rates are independent of quality – delivering the empirical regularity of Gibrat's law.

We consider an exogenous probability of entry  $z \in [0, 1]$  for each sector  $j$ . For now, we assume that such entry permanently displaces the incumbent firm, so that each good  $j$  is produced by a single firm. We relax this assumption when we consider escape competition. A firm with current quality  $q_j$  earns profit  $\pi_j = \Upsilon L q_j$  (see (5)). Its expected next period profit with innovation effort choice  $x_j$  is:

$$\begin{aligned} \mathbb{E}\pi_j &= (1 - z) [x_j \pi_j (1 + \lambda) + (1 - x_j) \pi_j] - \theta q_j x_j^2 \\ &= (1 - z) \pi_j (x_j \lambda + 1) - \theta q_j x_j^2 \\ &= q_j \left[ (1 - z) \Upsilon L (x_j \lambda + 1) - \theta x_j^2 \right]. \end{aligned}$$

Firms maximize this expected profit, leading to the equilibrium innovation choice:

$$x_j = (1 - z) \frac{\lambda \Upsilon L}{2\theta}, \quad (6)$$

<sup>12</sup> Alternatively, we could also use a convex innovation cost with an infinite limit as  $x_j \rightarrow 1^-$ .

and a resulting expected next-period profit:

$$\mathbb{E}\pi_j = (1 - z)\Upsilon Lq_j \left( 1 + \frac{\lambda^2(1 - z)\Upsilon L}{4\theta} \right). \quad (7)$$

Comparative statics for the innovation effort (6) yield the following important results:

**Result 1.** *Innovation effort does not depend on quality and decreases in the cost of R&D  $\theta$ :*

$$\frac{\partial x_j}{\partial q_j} = 0 \quad \text{and} \quad \frac{\partial x_j}{\partial \theta} < 0. \quad (8)$$

**Result 2.** *Innovation effort increases with market size:*

$$\frac{\partial x_j}{\partial L} > 0. \quad (9)$$

**Result 3.** *Innovation effort decreases with higher entry  $z$  (business-stealing competition):*

$$\frac{\partial x_j}{\partial z} < 0. \quad (10)$$

In addition, as anticipated, innovation effort responds positively to increases in the innovation step  $\lambda$ ; and responds negatively to increases in the marginal cost of production  $\eta$ .

### 3.3 Introducing escape competition

Our benchmark model so far delivers an unambiguously negative effect of competition on innovation (see (10)) due to the business-stealing channel emphasized by Schumpeter (1942). However, the empirical evidence supports a combination of *both* a positive and negative channel. As we detail in section 4 below, the ultimate direction for the impact of competition on innovation varies by country, industry, and across different types of firms and innovation efforts. In response, Aghion et al. (2005) and Akcigit et al. (2018) introduce an “*escape-competition effect*” that generates such a positive channel alongside the negative channel due to business-stealing. This new competition channel is driven by strategic interactions between multiple firms in a given product line: incumbent firms have an incentive to move ahead of their competitors. We now extend our benchmark model to incorporate a simplified version of those models with myopic firms to highlight this important mechanism.

Towards this goal, we introduce the possibility of multiple incumbent firms competing to produce a given intermediate good  $j$ . Those competing firms  $f$  produce goods that are perfect substitutes in quantities  $k_{fj}$ , yielding a final good production



function:

$$Y = \frac{L^\beta}{1-\beta} \int_0^N \left[ \sum_f q_{fj}^{\frac{\beta}{1-\beta}} k_{fj} \right]^{1-\beta} dj. \quad (11)$$

Firms compete in Bertrand pricing. Thus, as higher quality translates into a lower quality-adjusted cost, only firms with the highest quality level  $q_j$  (leaders) will produce. If there is more than one leader (neck-in-neck leaders), then competition amongst those firms will drive profits to zero: only a single leader earns positive profits. In this case, we assume that the innovation step  $\lambda$  is high enough that the firm is not constrained by limit pricing to its closest quality competitor and chooses the monopoly markup  $1/(1-\beta)$  we previously derived.<sup>13</sup>

### ***Innovation decisions with competition***

Given this outcome, any firm with non-leading quality (follower) will choose not to innovate: Even if it were a single step behind, the best case scenario for this firm would be to end up neck-in-neck with other leaders (if the follower's innovation is successful and none of the leaders' innovation is successful). And in that best case scenario, the follower would still end up with zero profit. Thus, when firms are myopic and only consider profits one-period ahead, followers do not innovate. This is no longer the case in our “fully dynamic” scenario. Yet, the main intuition for the escape competition channel that we describe below remains.

We maintain our previous assumption of an exogenous probability of entry  $z$ . However, we now allow for transitions to neck-in-neck leaders by assuming that entrants ( $E$ ) enter with a quality one step ahead of the leading firms<sup>14</sup>:

$$q_{Ej} = (1 + \lambda) \max_f \{q_{fj}\}.$$

Incumbent leaders still make their innovation decisions before this entry outcome is revealed. Just like the case of a single incumbent that we previously analyzed, any incumbent foresees that when entry does occur, their profit will be wiped out (to zero). Thus, when there is a single incumbent leader, its innovation decision will remain as we previously derived in (6). Letting  $f = 1$  denote a single leader:

$$x_{1j} = (1 - z) \frac{\lambda \Upsilon L}{2\theta} \quad (12)$$

<sup>13</sup> Alternatively, we could introduce an initial costly capacity commitment round amongst incumbents. Foreseeing the Bertrand competition in the following round, no incumbent with non-leading quality will pay this capacity cost – even when arbitrarily small.

<sup>14</sup> In our “fully dynamic” version, we further discuss the consequences of this type of technological spillover from incumbents to entrants.

### Neck-in-neck leaders

Consider a particular neck-in-neck firm  $f = 0$  with the highest quality level  $q_{0j}$  along with  $N_j \geq 1$  other firms  $f \neq 0$ . This firm will only earn positive profits next period if 1) its innovation is successful while its rivals' innovation is not and 2) there is no entry. This occurs with probability  $(1 - z) x_{0j} \prod_{f \neq 0} (1 - x_{fj})$ . In that case, the firm will earn a profit  $\Upsilon L q_{0j} (1 + \lambda)$ . Its expected next period profit is therefore given by (recall that its current profit is  $\pi_{0j} = 0$ ):

$$\mathbb{E}\pi_{0j} = (1 - z) x_{0j} \prod_i (1 - x_{ij}) \Upsilon L q_{0j} (1 + \lambda) - \theta q_{0j} x_{0j}^2.$$

Maximizing this expected profit and imposing symmetry ( $x_{fj} = x_{0j} \forall f$ ), yields the neck-in-neck innovation effort  $x_{0j}$  defined by:

$$\frac{x_{0j}}{(1 - x_{0j})^{N_j}} = (1 - z) (1 + \lambda) \frac{\Upsilon L}{2\theta}. \quad (13)$$

Comparing this innovation effort  $x_{0j}$  by neck-in-neck firms (see (13)) relative to that of a single leader (see (12)) highlights the new positive impact of escape competition, as well as an additional negative competition effect similar to the one we previously discussed related to entry. The new escape competition effect is captured by the  $(1 + \lambda)$  term replacing  $\lambda$  on the right-hand-side. When innovation is successful, neck-in-neck firms not only benefit from the innovation step  $\lambda$ —just like the single leader does—but in addition they “escape” the competition that was driving their current profit to zero (unlike the case of the single leader). This is the “one plus” part of the expression.

The additional negative competitive effect is reflected in the  $(1 - x_{0j})^{N_j}$  term in left-hand-side denominator of (13) for the neck-in-neck innovation effort. Those firms not only face potential replacement by an entrant (the  $1 - z$  term on the right-hand-side); they also face a similar replacement prospect at the hand of one of their other neck-in-neck rivals. Increases in the number  $N_j$  of such rivals therefore reduces the equilibrium innovation effort for all those firms. Nevertheless, a small enough innovation step  $\lambda$  will always lead to higher innovation effort by neck-in-neck firms relative to the single leader case ( $x_{0j} > x_{1j}$ ). That is because a low innovation step magnifies the additional escape competition “kick”, which is independent of that innovation step.<sup>15</sup> When there are  $N_j = 2$  neck-in-neck rivals, their innovation effort will be greater than the single leader ( $x_{0j} > x_{1j}$ ) so long as  $x_{1j} < (1 + \lambda)^{-1}$ . Since  $x_{1j} < 1$ , this makes clear how a low innovation step  $\lambda$  ensures this innovation ranking. In addition, for any innovation step  $\lambda$ , any change in the other parameters determining the leader's innovation ( $\Upsilon, L, \theta, z$ ) that pushes the innovation probability below  $(1 + \lambda)^{-1}$  will lead to higher innovation by the neck-in-neck rivals.

<sup>15</sup> As  $\lambda \rightarrow 0$ , the single leader's innovation also goes to zero, while the escape competition remains leading to positive innovation for the neck-in-neck rivals.

### Entry and industry evolution

Absent entry, a single leader is the absorbing state for this economy: Even if a sector  $j$  starts with several neck-in-neck rivals, those with unsuccessful innovation will drop out whenever one of their rival's innovation is successful. This ultimately leads to a single leader over time. Entry removes this absorbing state across sectors. The timing of entry is such that it does not completely discourage innovation, unlike the situation of a follower facing a known incumbent (given our assumption of myopic decision making for innovation). Thus, leaders and neck-in-neck rivals will still innovate when they face entry; and those whose innovation is successful will then end up as neck-in-neck rivals with the new entrant. This generates the evolution over time for the number of firms without any absorbing state.

### ***Discussion: myopic closed economy***

This closed economy version highlights the key market size and competition forces shaping innovation that have been featured in the literature, going back to Griliches (1957) and Schmookler (1966). In particular, it highlights the ambiguous role of competition on innovation incentives that have been debated since Schumpeter (1942) and Arrow (1972). In our model, increased entry and a larger number of neck-in-neck rivals generate the type of competition characterized by Schumpeter (1942) that unambiguously decreases the incentives for innovation: it reduces the value of any quality level  $q$ . We note that our assumption that entry replaces an incumbent with a given probability – holding the level of product variety fixed – does not play a key role here. In a model of Cournot or Bertrand competition with product differentiation, increased entry that increases the number of producers would lead to reduced innovation by incumbents. This would also hold in the monopolistic competition limit as the number of producers increases.

Escape competition embodies the type of competition change from follower to neck-and-neck, that generates the higher innovation incentives described by Arrow (1972). Alternative modeling approaches in the literature have focused on the impact of competition in reducing inefficiencies within the firm. This generates a link from increased competition to improved efficiency (a similar outcome to one induced by increased innovation). A remaining challenge is to explain why – prior to the increase in competition – a firm was not maximizing profits (the “X-inefficiency” of the monopolist posited by Leibenstein (1966)). Schmidt (1997) addresses this by developing a principle-agent model of mis-aligned objectives between managers and owners. Holmes and Schmitz Jr (2001) use this modeling approach to show how increased import competition leads to improved efficiency by reducing the incentives for firms to engage in non-productive activities aimed at worsening outcomes for competing firms. Aghion et al. (1999) extend this agency control problem to specifically incorporate innovation decisions. Managers face private costs of such technology adoption, inducing an asymmetry in their private returns for this adoption choice. The returns are higher when adoption would keep the firm solvent. Thus, when increased compe-

tion threatens solvency, there is a strong incentive to innovate – and this generates a positive impact of competition on innovation.<sup>16</sup>

### 3.4 Export market selection

We now consider export market selection in our baseline model without escape competition. Assume that there is an “iceberg” cost  $\tau \geq 1$  and a fixed cost of exporting  $\xi \bar{q}$  to access a foreign market with size  $L^F$ , where  $\xi > 0$  and  $\bar{q}$  indexes an exogenous quality level. Let  $L^D$  denote the size of the domestic market. In terms of timing, we assume that a firm makes a simultaneous innovation and export decision. The innovation and entry outcome (displacement probability) are then revealed.

The innovation choices for exporters and non-exporters are still determined by market size and competition in the same way as in the closed economy – except that the market size for exporters is higher than that for non-exporters and given by  $L \equiv L^D + \tau^{-\frac{(1-\beta)}{\beta}} L^F > L^D$ . This immediately implies that exporters innovate at a higher rate than non-exporters (see (6)) and earn higher expected profit (see (7)). A firm will export so long as the expected profit difference  $\mathbb{E}\pi_j|_{\text{exporter}} - \mathbb{E}\pi_j|_{\text{non-exporter}}$  is greater than the fixed export cost  $\xi \bar{q}$ . Substituting the expected profit from (7) with market demand  $L$  for the exporter and  $L^D$  for the non-exporter reveals that this inequality will be satisfied so long as the firm’s quality is above the lower bound threshold:

$$q^{\text{exp}} \equiv \frac{\xi \bar{q}}{(1-z) \Upsilon \left[ \frac{(1-z)\lambda^2 \Upsilon}{4\theta} (L^2 - (L^D)^2) + L - L^D \right]}.$$

Consider trade liberalization that lowers  $\tau$  to  $\tau'$ . This induces a decrease in the threshold  $q^{\text{exp}}$ , which is associated with the entry of new firms into the export market. The innovation rate of non-exporters is not affected by this liberalization. Exporters increase their innovation by

$$\Delta x_j^{\text{exp}} = \frac{(1-z) \Upsilon \lambda L^F}{2\theta} \left( \tau'^{-\frac{(1-\beta)}{\beta}} - \tau^{-\frac{(1-\beta)}{\beta}} \right),$$

whereas new exporters increase their innovation even more by

$$\Delta x_j^{\text{new}} = \frac{(1-z) \Upsilon \lambda L^F}{2\theta} \tau'^{-\frac{(1-\beta)}{\beta}} > \Delta x_j^{\text{exp}}.$$

One final remark is in order. When we consider an open economy, the entry rate  $z$  can be seen as the total sum of domestic and foreign entrants. Therefore as in the

<sup>16</sup> Bloom et al. (2021) also develop a model with firm inefficiencies in the allocation of resources to innovation activities. This results in “trapped factors” that are released to innovative activities when import competition increases.

closed-economy version of the model, import competition will lead to a reduction in innovation efforts in (6), unless we introduce strategic interactions (escape competition effect) among incumbent firms.

### ***Discussion: myopic open economy***

Once we introduce export market selection, our model replicates the key connections between exposure to export markets and the innovation and technology adoption choices of exporters and potential exporters that have been highlighted in the recent literature. The early literature using newly accessible firm-level data incorporating export status and technology choice (innovation) used exogenous (to the firms) trade liberalization episodes to highlight a causal link between an expansion in export exposure and the technology adoption choices of exporters (relative to non-exporters). Early examples are Verhoogen (2008), who finds that the Mexican Peso devaluation induced relatively more productive Mexican exporters to upgrade their product quality; Bustos (2011), who finds that Mercosur induced Argentine exporters to adopt new technologies; and Lileeva and Trefler (2010), who find that CUSFTA induced Canadian exporters to the United States to both adopt new technologies and increase their product innovation.<sup>17</sup> Our model's prediction that exporters innovate at a higher rate than non-exporters, and that export market liberalization induces increased innovation rates for exporters relative to non-exporters matches these findings. Our model also features the theoretical predictions and empirical confirmations made by Bustos (2011) and Lileeva and Trefler (2010) that trade liberalization induces the largest innovation response by new exporters. Once we consider our model's prediction with respect to heterogeneity in innovation capacity  $\theta$ , our model also replicates Lileeva and Trefler's (2010) findings of negative sorting based on firm performance (quality  $q$  in our model) amongst the new exporters: The largest innovation responses to trade liberalization are made by new exporters with relative lower quality.

Our model's predictions are also closely related to Aghion et al. (2018), who show that increases in export market demand leads to (after several years) increases in new patents for most exporters to those markets. Aghion et al. (2018) develop a model that features a very similar market size effect for endogenous innovation. Their model also features different innovation incentives across the distribution of exporters driven by endogenous markups. In the long run (with free entry), those markup responses affect the relative magnitude of the market size and competition (business stealing) effects for different exporters: the positive market size effect dominates for high-performing exporters; whereas the negative business stealing effect dominates for the worse-performing exporters. Long et al. (2011) also analyze a model of endogenous innovation where the relative magnitude of the market size and business stealing effect varies in response to trade liberalization between two symmetric countries.

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<sup>17</sup> Those papers also develop models with heterogeneous producers and endogenous technology choices where the export market size effect induces a technology upgrade. Those models follow the work of Yeaple (2005), who analyzes a model of technology choice by ex-ante representative firms: Firms jointly choose a higher returns-to-scale technology along with exporter status.

In their model, the positive market size effect dominates – and trade liberalization leads to increases in innovation – when the trade costs are low. However, that relative magnitude is reversed when trade costs are high, and trade liberalization leads to decreases in innovation.

### 3.5 Dynamic model with forward-looking firms

We now show how this myopic model can be generalized with forward-looking firms beyond the immediate following period. We return to our closed economy specification. As in Aghion and Howitt (1992) and Grossman and Helpman (1991a), innovating firms maximize the discounted sum of expected profits by choosing their innovation efforts. (However, unlike those models, the innovation effort is still exerted by incumbents.) Thus, the economy's interest rate has a direct impact on innovation decisions. The equilibrium interest rate is determined by the representative household's intertemporal utility maximization subject to its budget constraint, which delivers the standard Euler equation. This connects the equilibrium interest rate to the rate of time preference. For instance, when the utility is logarithmic, the interest rate is simply  $r = g + \rho$  where  $\rho > 0$  is the discount rate of the household.

We switch to a continuous time representation where we convert all per-period outcomes to flow rates. This includes the entry and innovation probabilities – previously bounded in  $[0, 1]$  – that are now also converted to non-negative flow rates  $z$  and  $x_j$ . Firms maximize the net present value of their profit flow  $\pi_j = \Upsilon L q_j$  (see (5)) at the interest rate  $r$ . This value function  $V(q_j)$  satisfies the Hamilton-Jacobi-Bellman equation:

$$rV(q_j) - \dot{V}(q_j) = \max_{x_j} \left\{ \begin{array}{c} \pi_j - \theta x_j^2 q_j \\ + x_j [V(q_j(1 + \lambda)) - V(q_j)] \\ - zV(q_j) \end{array} \right\}.$$

We can now conjecture the following form for the value function

$$V(q_j) = v q_j. \quad (14)$$

This further implies:

$$v[r + z] = \max_{x_j} \left\{ \Upsilon L - \theta x_j^2 + x_j \lambda v \right\}.$$

The solution to this value function is:

$$v = \frac{[r + z] - \sqrt{[r + z]^2 - \frac{\lambda^2}{\theta} \Upsilon L}}{\frac{\lambda^2}{2\theta}},$$

and the resulting innovation effort is:

$$x_j = \frac{z+r}{\lambda} - \sqrt{\left(\frac{z+r}{\lambda}\right)^2 - \frac{\Upsilon L}{\theta}}. \quad (15)$$

We recover the same comparative statics for this endogenous innovation effort as in the myopic case:

$$\frac{\partial x_j}{\partial z}, \frac{\partial x_j}{\partial \theta} < 0 \text{ and } \frac{\partial x_j}{\partial L}, \frac{\partial x_j}{\partial \lambda} > 0.$$

In addition, the interest rate  $r$  now also affects the equilibrium rate of innovation. As is the case in many dynamic models, a change in the interest rate has identical consequences as a change in the continuation probability – indexed by the entry displacement  $z$ : A given percentage increase in either one reduces the innovation rate by the same amount.

Substituting (5) and (4) into (1), we get

$$Y_t = \frac{\Upsilon L}{\beta(1-\beta)} Q_t$$

where  $Q_t \equiv \int_0^N q_{jt} dj$  is the quality index of the economy. This implies that the growth rate of  $Y_t$  is equal to the growth rate of  $Q_t$ . Note that  $x_j$  is the same for all  $j \in [0, N]$ , hence  $x_j = x$ . Now we can express the change in the quality index after a small time interval  $\Delta t$  as,

$$Q_{t+\Delta t} \equiv \int_0^N [(x\Delta t + z\Delta t)(1+\lambda)q_{jt} + [1-(x\Delta t + z\Delta t)]q_{jt}] dj$$

Subtracting  $Q_t$  from both sides, dividing by  $\Delta t$ , taking the limit as  $\Delta t \rightarrow 0$  and dividing again by  $Q_t$ , we can express the growth rate as

$$g = \lim_{\Delta t \rightarrow 0} \frac{Q_{t+\Delta t} - Q_t}{\Delta t} \frac{1}{Q_t} = (x+z)\lambda.$$

Together with the Euler equation and (15), this expression pins down the growth and innovation rates, as well as the interest rate  $r$ , as functions of exogenous variables only.

Economic growth in this economy is driven by both incumbent and entrant innovation. The growth in this framework is typically not efficient due to various reasons: First, monopoly markups in the intermediate good sector imply that too few resources are allocated to that sector relative to the competitive final good sector. Second, intertemporal technology spillovers are not fully internalized in the sense that innovating firms collect the return to their innovation only when they are market leaders and entrant innovation generates a business-stealing effect for incumbents. Due to these forces, there is under-investment in R&D so long as the innovation step size  $\lambda$

is above a given threshold. In other words, when the technology spillover is “large enough” and dominates the business-stealing effect.

Spillovers have been at the heart of all innovation-led growth models. In Romer (1990), and Rivera-Batiz and Romer (1991) the innovation production function takes the following form:

$$\dot{N} = \delta H N, \quad (16)$$

where  $\dot{N}$  is the number of new ideas at any instant and  $H$  is the level of human capital allocated to R&D. Note that any new idea that is produced in this period contributes to future idea creation by increasing the stock of knowledge (the right-hand side of (16)). Hence a typical prediction for this framework is that there is too little R&D in equilibrium due to these uninternalized spillovers by the inventors. The model by Aghion and Howitt (1992) adds the notion of creative destruction where new entrants replace incumbents. Such a turnover in the model introduces the business-stealing effect, in addition to the usual intertemporal spillover effect. While spillovers lead to underinvestment, business stealing lead to overinvestment since more frequent innovation in the economy discourages future inventors due to reduced average monopoly duration. Thus, the standard quality ladder models by Aghion and Howitt (1992), Grossman and Helpman (1991b), and Klette and Kortum (2004) predict that there is a certain innovation step size threshold  $\lambda^*$  that determines whether there is too much or too little innovation. When the innovation step is below that threshold ( $\lambda < \lambda^*$ ), the business-stealing effect dominates and there is too much innovation. And conversely, there is too little innovation when the innovation step is large enough ( $\lambda > \lambda^*$ ).

In quality ladder models where innovation is done both externally and internally (i.e., horizontally and vertically), the sources of inefficiencies become more complex. As in Akcigit and Kerr (2018), if firms produce internal innovations that improve the quality of their existing product lines, the negative business stealing effect gets muted. However, if firms innovate externally and expand into a new sector where the firm did not previously operate, then the usual business-stealing effect might lead to over-investment in R&D. In our current model, entrants produce external innovations by expanding into a new sector whereas incumbents produce internal innovations by improving their existing product lines. Hence, incumbents generate only positive intertemporal spillovers whereas entrants generate both spillovers and business stealing effects.

### ***Escape competition with forward-looking firms***

We now briefly summarize the main predictions of this dynamic model when it is extended to incorporate competition between incumbent firms.<sup>18</sup> Due to the limitations of the myopic case we previously described, followers did not innovate because they did not look beyond the next period, which – at best – would put them in a neck-in-neck position with their rival implying stiff Bertrand competition and profits

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<sup>18</sup> See Akcigit et al. (2018) for a fully fleshed-out model with two active incumbents.



driven to zero. In this “fully dynamic” setting, a follower now looks beyond this next period and foresees the possibility of moving into a leading position in subsequent periods. Thus, followers will now innovate, eliminating the undesirable property of no innovation effort that we derived for the myopic case. However, followers will always innovate with lower effort than neck-in-neck firms – maintaining the same crucial ranking that we had previously derived for the myopic case. And also similar to that case, those neck-in-neck firms will innovate at higher rates than a single leader whenever the size of the innovation step  $\lambda$  is low enough.<sup>19</sup> Thus, the main intuition for this escape competition effect – along with the ambiguous trade-off for the overall impact of competition on innovation – that we previously described remains.

In this framework, growth is driven directly by the innovation of leaders and neck-and-neck firms since their innovations improve the technology frontier of the economy. Growth is affected indirectly by the followers since their innovations do not directly contribute to the technology frontier, but they incentivize the leaders to exert more effort to escape competition.

Note that in addition to the earlier inefficiencies, there is another source of inefficiency in this model. Entrants and followers do not internalize their impact on reduced markups when they innovate. Due to all these different inefficiency margins, innovation policy could be quite effective in increasing growth and welfare. For instance, Acemoglu and Akcigit (2012) show the importance of the “trickle-down effect” in this class of models: Supporting firms with higher quality levels induces an additional dynamic incentive for the lower quality firms. Their return to higher innovation effort is compounded by the additional government support only available to successful innovators with higher quality. Relatedly, Akcigit et al. (2018) show that R&D subsidies can generate significant gains and protectionist policies could generate very significant dynamic welfare losses due to reduced innovation, generated by the weakening international escape-competition effect.

### ***Endogenous entry***

In this section, we introduce an endogenous entry margin and highlight the solution of the dynamic model with forward-looking firms. To that end, assume that there is a linear entry cost  $C(z) = \kappa q_j z$ . Then the same conjecture as in (14) would imply:  $v q_j = \kappa q_j$ . Therefore, the value function is pinned down as

$$v = \kappa.$$

Following the same steps that we previously derived in Section 3.5, we can show that the endogenous entry rate is

$$z = \frac{\kappa \lambda^2}{4\theta} + \frac{\pi_j}{\kappa} - r.$$

<sup>19</sup> Also, just like in the myopic case, the innovation by the leader goes to zero along with the innovation step  $\lambda$ , whereas the innovation effort by the neck-in-neck firms remains positive in that case.

Finally, the equilibrium incumbent innovation decision becomes

$$x_j = \frac{\lambda \kappa}{2\theta}. \quad (17)$$

We see how the introduction of endogenous entry eliminates the market size channel for innovation. As is the case with static models featuring monopolistic competition with endogenous entry, the shape of the preferences plays a crucial role in driving this implication. When those take the form of a constant elasticity of substitution, the increased competition induced by endogenous entry exactly offsets the direct effect of increased market size, leaving the equilibrium size of firms unchanged. This is what eliminates the impact of market size on innovation in (17). As has been studied extensively in static models, moving away from constant price elasticities – due to either preferences with variable elasticity of substitution or oligopolistic competition with constant elasticity – reinstates a role for market size in determining the equilibrium size of firms. In turn, this also reinstates a link from market size to innovation.

The offsetting market size and competition effects can also occur in Ricardian models of trade without free entry, as highlighted by Eaton and Kortum (2001). This is a direct consequence of the model assumptions, in particular, a single industry and undirected research. Somale (2021) drops these assumptions, calibrates the model, and finds a positive net effect.

### ***Discussion: dynamic open economy***

Atkeson and Burstein (2010) and Impullitti and Licandro (2018) both develop dynamic models that feature those same market size and business stealing channels – along with endogenous export market participation. They both analyze trade liberalization between two symmetric countries. In both cases, the market size effect dominates, and trade liberalization leads to increased innovation by exporters. Those papers focus on the implications of those innovation responses for welfare and the dynamic gains from trade. The market equilibrium analyzed by Atkeson and Burstein (2010) is efficient, and they recover a “dynamic” version of the Arkolakis et al. (2012) (ACR) welfare result: the impact of firm heterogeneity (including the fact that exporters and non-exporters make different innovation decisions) does not affect the welfare gains from trade liberalization to a first-order – because firm heterogeneity is “as-if” optimally chosen by a welfare-maximizing planner. On the other hand, the market equilibrium in Impullitti and Licandro (2018) features oligopoly competition and is not efficient. This breaks the ACR welfare result, and they find that the selection of firms into exporting and higher innovation generates substantial dynamic welfare gains from trade liberalization. In addition to the market size and business stealing channel, Akcigit et al. (2018) also model the escape competition channel in a dynamic model that is calibrated to U.S. patent and trade data from 1975–1995. The market equilibrium in this model is also not efficient, and trade policy has a substantial impact on welfare dynamics. In particular, a rise in tariffs partially prevents profit losses of domestic producers due to foreign competition. This static benefit is counteracted by two other forces. First, replacing better-quality imported goods with

inferior domestic counterparts has a substantial negative effect on aggregate productivity. Second, protecting domestic firms in import-competing sectors reduces their “escape-competition” incentives and leads to lower innovation. In the long run, this dynamic force on innovation incentives becomes more dominant and generates significant losses in welfare.

Costantini and Melitz (2009) and Burstein and Melitz (2013) focus on the implications of trade liberalization for the transitional dynamics. In particular, both papers highlight that the announcement and perceived duration of trade liberalization have substantial consequences for those transitions when innovation choices are endogenous. When trade liberalization is announced, even when not yet implemented, forward-looking firms immediately adjust their innovation responses. Similarly, if trade liberalization is enacted, but perceived to be only temporary, then forward looking firms do not substantially adjust their innovation responses – whereas those responses are substantial if trade liberalization is perceived to be permanent (or longer-lasting).

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#### 4 Additional evidence on the market size and competition channels

Strongly motivated by empirical evidence, we have developed a modeling structure where endogenous innovation responds positively to market size and responds non-monotonically to changes in competition. Globalization affects both of those market size and competition channels. Indeed, much of the empirical evidence is based on studies analyzing the innovation responses to changes in globalization. The impact of the market size channel can be measured by isolating cases where export market liberalization leads to increased market access for existing and new exporters in the domestic market. Similarly, the impact of the competition channel is measured by isolating cases of import trade liberalization. These studies exploit differential changes in import and export tariffs, as well as other specific changes in trade policy with asymmetric consequences for imports and exports. Studies based on firm-level studies can also exploit variations across non-exporters (who do not benefit from increases in export market access) and exporters. Furthermore, changes in market access for exporters can also be identified based on customs data detailing which products are exported to which destinations.

The recent survey by Shu and Steinwender (2019) summarizes those findings for innovation responses, separating out the impact of increased market access from exports and the impact of increased competition from imports. For the former—increased export market access—the impact on innovation is unambiguously positive across those studies (cf. Shu and Steinwender, 2019, Table 3). And the magnitudes are large: In one of the broader studies spanning 60 countries, Coelli et al. (2022) find that the global decline in tariffs in the 1990s can explain 7% of global innova-

tion (patents) during that period.<sup>20,21</sup> In terms of the ultimate impact of innovation on productivity, Lileeva and Trebler (2010) find that the free trade agreement signed between Canada and the United States (CUSFTA) led to innovations by Canadian exporters that increased their within-firm productivity by 6%. In the case of France, Aghion et al. (2019) find that the patenting responses to increased export market access are further concentrated within a subset of relatively more productive exporters.

Another empirical approach to isolate the impact of increased market access from export market expansion relies on structural dynamic estimation. This approach accommodates the dynamic feedback loop between export market size and the firms' R&D and export market participation decisions. In addition, it also accommodates the modeling of other dynamic channels such as learning spillovers (from export market participation) that we discuss in the next section. Using this approach and Taiwanese firm-level data for the electronics industry, Aw et al. (2011) confirm the results from the econometric studies based on asymmetric trade liberalization that we previously summarized: They also find a strong positive response of R&D to export market expansion. On the other hand, the authors find little evidence for the learning spillover channel. Peters et al. (2018) extend those methods to allow for different market size impacts for domestic and export sales. Using data on German firms, they find that changes in export market size have a substantially stronger impact on innovation relative to changes in domestic market size.

In contrast to the unambiguously positive impact of increased market access from exports, the results for the impact of increased competition from imports are a bit more ambiguous (cf. Shu and Steinwender, 2019, Table 2). This stems from some mixed results for the impact of increased competition in certain developed economies. The studies of import market liberalization in developing countries all find positive impacts on innovation. This is confirmed in the cross-country study by Gorodnichenko et al. (2010) across developing European countries. They find robust positive increases in broad innovation measures at the firm-level from increased import competition. And even across the broader set of 60 countries analyzed by Coelli et al. (2022), the authors find a robust increase in patenting following increases in import competition from trade liberalization in the 1990s.<sup>22</sup>

In one prominent study focused on a developed economy, Autor et al. (2020) find that increased competition from Chinese imports had a negative impact on the patenting activity of U.S. manufacturing firms. This negative impact is mainly driven by a large negative response among initially less profitable and less capital-intensive firms.

<sup>20</sup> Across countries, that innovation response is stronger in developed countries as well as countries that were initially less open to trade.

<sup>21</sup> They also find a positive impact for competition from imports with a roughly similar magnitude.

<sup>22</sup> In studies focused on particular countries, Teshima (2009) and Iacovone (2012) find positive responses of R&D in Mexico following NAFTA; Bombardini et al. (2018) and Fieler and Harrison (2018) find positive patenting and new product introduction responses in China following its WTO accession; and Ahn et al. (2018) also finds a positive patent response by Korean manufacturing firms following increased competition with China.

However, in the developed European economies, Bloom et al. (2016) find an opposite effect for the impact of increased Chinese import competition: European firms respond by increasing their innovation activities (including patenting). One possible explanation for this divergence is that the innovation responses are heterogeneous and even non-monotonic across different types of firms and types of innovation activities: As highlighted by our modeling framework, the direction of the innovation response may be sensitive to the characteristics of the competing firms.<sup>23</sup> For example, Autor et al. (2020) find no statistically significant effect for the patenting responses of above-median performing firms, whether they are ordered by either labor productivity, capital intensity, or profitability.

Another explanation for the non-monotonic impact of increased import competition is that this shock combines both a direct competition shock to the firms' output market; but also a potential positive spillover shock to the firms' input market. We discuss this technological spillover via imported intermediates in the following section. Returning to the impact of China's import competition shock for the case of French manufacturing, Aghion et al. (2021) find a negative response in innovation activity only for the subset of French firms that do not also benefit from the use of imported Chinese intermediate goods.

The innovation responses to increased import competition may also be sensitive to the type of innovation activity: whether it is directed at product innovation – such as increasing the differentiation of the firms' product portfolio (potentially through the introduction of new products or the refinement of existing ones) – or directed at process innovation that reduces the firms' production costs. Returning to the case of U.S. firms and the increased competition from Chinese imports, Hombert and Ma-tray (2018) find evidence of both negative and positive responses that are sensitive to the type of innovation considered. The positive responses are driven by product innovation directed towards more differentiated products. Yang et al. (2021) also find similar evidence for Canadian firms, as do Fieler and Harrison (2018) for the “reverse” case of Chinese firms who also faced increased competition from Foreign exporters to China following its WTO accession. Evidence of heterogeneous innovation responses across firms is also present for the case of those Chinese firms: Bombardini et al. (2018) find that the positive response is concentrated amongst the relatively more productive firms.

Lastly, there is also an empirical literature evaluating the market size and competition channels for innovation based on shocks that do not involve trade. Given the title of this chapter, that evidence falls outside our purview, but nonetheless fits well with predictions of our theoretical framework. Demographic changes are one prominent example of market size shocks that are not related to export markets. Acemoglu and Linn (2004) exploit this shock for the United States. They find that demographic changes driving the demand for particular drugs induce more innovation in those

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<sup>23</sup> They influence the balance between the negative profit destruction channel and the positive escape competition channel.

drugs, as measured by FDA approvals. Demographics also affect the demand (hence market size) for different types of products consumed by households with different income levels. Jaravel (2018) finds that U.S. firms respond to those market size variations by investing in product development targeted at growing demographic groups.<sup>24</sup>

As was the case for the evidence based on import competition, the evidence for the impact of increased competition not related to trade on innovation is also non-monotonic. This highlights once again the relevance of opposing profit destruction and escape competition channels on innovation. In an early study for United Kingdom using concentration and profit differences across industries, Nickell (1996) finds that those proxies for competition are strongly correlated with increased firm performance. In their empirical test for those opposing escape-competition and profit-destruction channels for innovation, Aghion et al. (2005) extend this data to also measure patenting responses; and they further instrument for the differences in the competition proxies across industries with domestic policy changes related to competition, such as antitrust and privatizations. They find evidence of a non-monotonic, more specifically and inverted-U, relationship between competition and innovation across the U.K. sectors: For most sectors, the relationship is positive, but it turns negative for the sectors with the highest levels of competition (again, as measured by the instrumented proxies such as concentration and profit margins).

There have also been studies of very specific “shocks” that increase competition in a sector. Matsa (2011) looks at supermarkets following Walmart’s entry across the United States. He finds that the local supermarkets responded to Walmart’s entry into their market by investing in computerized inventory management systems, leading to a 10% decrease in stockouts. On the other hand, Goettler and Gordon (2011) find evidence for a negative impact of competition in the U.S. semiconductor industry: following the entry of AMD into that industry, they find that Intel reduced its innovation in product quality by 4.2%.

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## 5 Learning-diffusion models of technology spillovers

So far, we have focused on models (along with their empirical predictions) where changes in trade regime impact the *incentives* for endogenous innovation – but not the innovation process itself. Another literature has analyzed a connection between trade and growth, where the latter is driven by some form of technology spillovers. Those spillovers can be a direct by-product of trade, such as a domestic producer learning from contact with Foreign sellers (“learning-by-exporting”) or from contact with Foreign input suppliers. But those spillovers could also occur across producers operating in a given market. Globalization in the form of multinational production – Foreign firms producing in the domestic market – would then directly affect those potential

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<sup>24</sup> In this case, demand is growing for the wealthier households. The induced innovation in new products customized for those consumers contributes to U.S. income inequality.

technology spillovers.<sup>25</sup> Even in the absence of multinational production, knowledge spillovers between domestic producers are influenced by trade whenever those producers are heterogeneous. Trade matters because it affects the selection of those firms (who survives); and this, in-turn, affects the extent of knowledge spillovers.

Building on endogenous growth theory in closed economies, Grossman and Helpman (1991c) showed how technology spillovers embodied in trade induced a link from trade to growth. Peretto (2003) extends this modeling approach to an oligopolistic market structure. And Grossman and Helpman (2018) provide an extension to heterogeneous workers, analyzing the consequences of growth for inequality. Baldwin and Robert-Nicoud (2008) consider an expanding variety model of endogenous growth in an open-economy setting with heterogeneous producers. In this case, the knowledge spillovers associated with trade decrease the cost of new varieties. This generates another potential link from trade to growth. However, they point out that trade can also have a negative impact on growth if trade reduces the number of incumbent producers – which acts as a break on the expanding variety growth engine. Eaton and Kortum (2001) consider a model of trade and growth with technology spillovers across countries that are not related to trade (those spillovers are exogenously specified as bilateral parameters). More recently, Alvarez et al. (2013) provide a structural interpretation for the diffusion mechanism from sellers (including Foreign sellers) to domestic producers. They show how trade has a positive impact on this diffusion process, and how it generates a law of motion for the distribution of firm productivity.

Sampson (2016) develops the idea that trade matters for growth because it affects the selection of heterogeneous producers; and tougher selection generates growth because entrants learn from that selected subset of producers that survive: this is a knowledge spillover from domestic incumbents to domestic entrants. The result is a model of growth “without scale effects” that fits the empirical micro-level evidence: a stable relative distribution of entrants and incumbents over time. In this model, various forms of trade liberalization generate tougher selection for domestic producers (a standard impact of trade liberalization from static models), and thereby induce faster growth – a dynamic gain from trade. More recently, Perla et al. (2021) also analyze a model of technology spillovers amongst domestic producers. In their model, the learning process occurs between incumbent firms. A lower productivity firm can learn – a costly search process – from a higher productivity firm and improve its productivity. Similar to Sampson (2016), trade liberalization toughens selection and improves the distribution of surviving incumbents. This increases the incentives for the lower productivity firms to undertake that search process: an endogenous innovation response to trade liberalization. In this model, the relatively worse performing firms innovate more than their better performing counterparts. This is similar to one aspect of escape competition: that neck-in-neck producers innovate more than the leaders. However, escape competition also predicts that the followers (the worse performing firms) innovate less than the mid-level neck-in-neck producers.

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<sup>25</sup> See survey in Keller (2010) for a review of this literature.



Buera and Oberfield (2020) analyze a multi-country dynamic model that incorporates both knowledge diffusion channels we have just described: from sellers as well as domestic producers. They contrast the dynamic implications of both channels – as a function of the magnitude of the spillovers. They calibrate their model to match the evolution of both TFP and trade across a wide set of countries; and highlight that knowledge diffusion is a key component that explains the joint evolution of those outcomes over time and across countries.

There is also more direct evidence of spillover links between buyers and sellers in different markets. The strongest and most pervasive evidence supports such a link from intermediate good producers to their Foreign buyers. In other words, importers of Foreign intermediate goods benefit from this technology transfer, which shows up in higher productivity, R&D, and new product introductions (cf. Shu and Steinwender, 2019, Table 4).<sup>26</sup> The evidence supporting a similar link in the opposite direction from a Foreign buyer to the producer – the “learning-by-exporting” channel – is more limited. In some cases documented by Van Biesebroeck (2005) and De Loecker (2007), new exporters enjoy productivity improvements shortly after their export market entry. However, Costantini and Melitz (2009) point out that this evidence is also consistent with a forward-looking innovation response to anticipated export market participation (without any technology spillover from Foreign buyers).<sup>27</sup> Atkin et al. (2017) address this identification problem by setting up a randomized controlled trial for Egyptian rug manufacturers; and they do find evidence for a “learning-by-exporting” channel: Contact with Foreign buyers improves the quality of the rugs, and the efficiency with which they are produced.

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## 6 Conclusion

What is the impact of international trade, and globalization more generally, on innovation incentives? How does innovation affect firms’ exporting decisions? In this chapter, we review the literature explaining and documenting those links. We build a theoretical framework that incorporates many of the mechanisms highlighted in that literature.

First, access (or increased access) to export markets increases innovation incentives through a “market size” effect. Second, increased entry by foreign firms into domestic markets generates a “business stealing” effect, which reduces the duration of monopolies and hence the innovation incentives for those incumbents. Third, to the extent that domestic incumbents can “escape” this Foreign competition via successful innovation, then that competition can also induce higher innovation responses by

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<sup>26</sup> In addition to the studies mentioned in that Table, Gopinath and Neiman (2014) find that the severe import contraction following the Argentine Peso crisis induced large productivity losses for Argentinian firms whose Foreign capital imports were curtailed by the crises.

<sup>27</sup> As we previously mentioned, Aw et al. (2011) run a “horse-race” between this export as anticipated innovation consequence and a learning-by-exporting spillover, and find little evidence for the latter.



well-positioned domestic incumbents. Our theoretical framework incorporates those key channels, and we review the evidence supporting each one. In addition to influencing those incentives for innovation, international trade can also directly impact technology spillovers between markets; and we also review this related literature.

As we review in this chapter, much progress has been made identifying and quantifying those important links between trade and innovation. But there is also plenty of room for new contributions.

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