Trade and Innovation: Unraveling a Complex Nexus

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Abstract

This paper reviews the theoretical and empirical economic literature on the innovation effect of international trade. To this end, we focus on technological innovation that targets product characteristics. We highlight three main channels through which international trade can affect innovation by domestic firms: increasing market size, intensifying market competition and facilitating foreign sourcing. While the market size effect of trade on domestic innovation is found to be predominantly positive, the effects of market competition and foreign sourcing are ambiguous and can depend on a variety of factors. Moreover, the impact of trade on innovation is likely heterogeneous across firms.

1. Introduction

Innovation is the key engine of modern economic growth. Among the multitude of factors that can shape innovation activity, international trade has been considered a prominent one.[3] Casual observations reveal the empirical relevance of this view. For instance, Figure 1 depicts the evolution of global patent applications and world exports of goods and services which are normalized by their values in 1985.[4] As is clear, both variables have been steadily increasing over time, suggesting concurrent expansions of global trade and innovation. More importantly, there exists a marked correlation between the two variables

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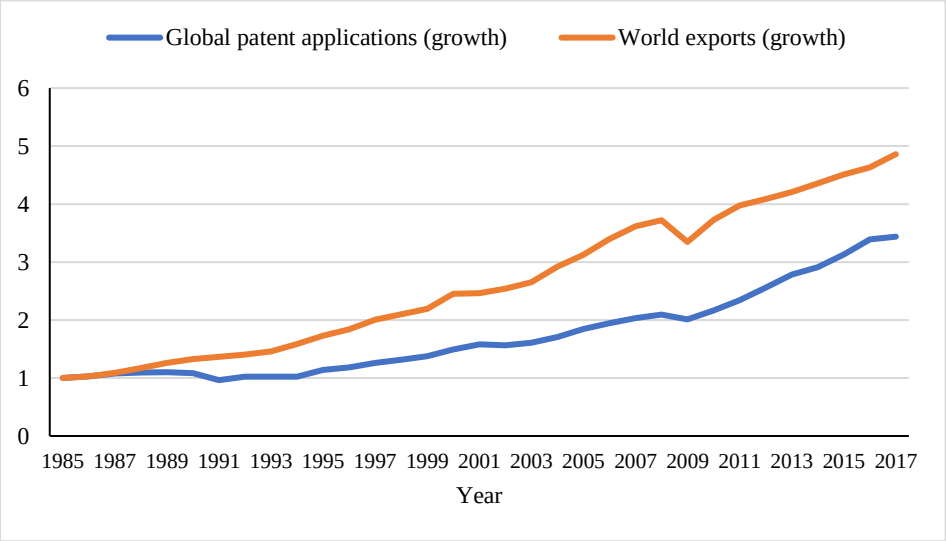
[3]One important reason is that international trade can play a vital role in international expansion of firms which is conducive to their innovation activity. Specifically, firms can serve foreign markets mainly through exporting or foreign direct investment (FDI), but the fixed cost associated with FDI is typically much higher and is only affordable to highly productive firms. As a result, most firms serving foreign markets opt for exporting rather than FDI. Moreover, international trade is important even to multinational firms that undertake FDI. For one thing, multinational firms engage in substantial intra-firm trade between their subsidiaries across countries. For another, due to uncertainty multinational firms often export to new foreign markets before entry via FDI.
[4]To control for price changes the world exports are calculated based on constant 2010 US$.

over the examined period. Although this correlation does not necessarily imply causation, it is also difficult to contend that international trade has barely contributed to the surge in global innovation.

Figure 1: Global Innovation and Trade: 1985-2017



Source: World Intellectual Property Organization and World Bank

In this paper, we provide a systematic review of the economic literature on the relationship between trade and innovation. While such a relationship is clearly two-way, our primary concern is the effect of trade on innovation.[5] In particular, we take the perspective of domestic firms and examine how their incentives and capacities for innovation may be affected by trade liberalization such as reductions in tariff barriers or transportation costs.[6] To this end, we focus on technological innovation that targets product characteristics as it

[5]Thus our discussion attempts to identifying the "exogenous" effect of trade on innovation. We acknowledge that the reserve causality may well exist, that is, a firm's innovation activity can have notable consequences on its participation in international trade. In fact, an established economic and business literature has documented that innovation can affect firm's trade behavior (Barrios et al., 2003; Kyläheiko et al., 2011; Filipescu et al., 2013). Specifically, some studies find that product innovation can play a key role in firm's decision about entering the export markets (Basile, 2001; Cassiman and Golovko, 2010; Becker and Egger, 2013). Some find that innovation may also affect firm's performance on the international market (Wakelin, 1998; Roper and Love, 2002).

[6]Here we focus on changes in trade policy or transportation costs as driving firm's exporting and importing decisions due to the common practice of the economic literature. For example, it is well-known that the neoclassical and the new trade theories assume the market structure as perfectly and monopolistically competitive respectively. Since these models abstract from strategic interactions between firms, levels of tariffs and transportation costs are key factors determining how much firms export and import. This is also true of much of the empirical trade research which is built upon the framework of the neoclassical or the new trade theory.

is the subject of most extant studies. We examine two common types of technological innovation: product and process innovations. Product innovation can lead to variety expansion, that is, the introduction of a new good or service; or it may result in quality upgrading which refers to betterment of the functions of an existing product. In contrast, process innovation improves production technology and thus reduces the cost of producing a good or service.

Our discussion identifies three main channels through which trade impacts innovation by domestic firms. The first channel is market expansion induced by improved export opportunities. Intuitively, exporting allows firms to sell in a larger number of markets, which implies greater profitability and thus higher incentives for innovation. Moreover, increased market scope tends to promote both product and process innovations by exporting firms, although the extent to which each type of innovation responds may depend on various factors. For example, theoretical analysis reveals that larger scope of product differentiation induces relatively more product innovation than process innovation. In addition, market similarity may play a role such that exporting to richer markets creates incentives especially for quality-upgrading innovation. Empirical evidence seems to support these propositions.

The second channel is intensified market competition due to international trade. It is well-established in the industrial organization literature that market competition can affect innovation in both directions. This verdict applies to trade-induced competition as well. That said, theoretical research has identified certain conditions under which trade-induced competition can foster domestic innovation. These include industry structure being neck-and-neck, resources being used inefficiently and consumers valuing brand size, etc. Theory also predicts that the innovation effect of competition is likely to be heterogeneous across firms. Empirically, a notable stylized fact is that the impact of trade-induced competition on innovation is geographically dependent. Specifically, it is found that import competition tends to promote innovation in Europe and developing countries but reduce it in North America. There also exists preliminary evidence that import competition affects process innovation relatively more than product innovation. Finally, robust evidence has been

found for differential innovation effects of import competition, that is, less productive firms are more likely to reduce innovation when facing tougher competition from foreign firms.

The third channel concerns import of intermediate inputs, or equivalently, foreign sourcing. Theoretically, foreign sourcing can either complement or substitute domestic innovation. For one thing, foreign sourcing can enhance innovation by the participating firms through channels such as production cost reduction, knowledge spillovers and absorptive capacity improvement. For another, foreign sourcing may dampen domestic innovation as it allows the sourcing firms to acquire inputs instead of developing them through in-house R&D. Existing empirical evidence, although limited, appears to be consistent with both effects at work. Particularly, when foreign sourcing enhances domestic innovation, evidence has been found for the channel of knowledge spillovers.[7]

It is worth mentioning two caveats to the scope of the paper. First, this paper does not concern innovations over organization, management and marketing which are essential components of firm's innovation portfolio. There are two reasons for leaving out this important subject. On the theoretical front, these alternative types of innovation may have properties quite different from that of technological innovation. For example, Birkinshaw and Mol (2006) point out that managerial innovation tends to entail more participation of external agents, and diffusion of new management practices often takes significantly longer time. Besides, Chen (2006) shows that the impact of marketing innovation can differ markedly from that of product and process innovations. On the empirical front, relevant research remains scarce due to the difficulty of quantitatively measuring managerial and marketing practices (Bloom and Van Reenen, 2010). For these reasons, we have chosen to restrict our attention to technological innovation.

[7]It is worth noting that the three channels we examine can be interdependent. For instance, an increase in export market size may induce entry of firms and this can in turn intensify market competition. Also, firms may change their decisions about foreign sourcing when facing better export opportunities or tougher import competition. Hence, when discussing the innovation effect of each channel we implicitly assume the other channels are held unchanged.

The second caveat is that we do not examine the literature on the role of "national systems of innovation" as discussed by Dosi (1988) and Fagerberg (1994), which emphasizes the intuitive idea that institutional context matters in shaping what firms do and how they do it. This is no doubt an important consideration, particularly in explaining technological differences across firms and their impact on growth rates. However, since our focus here is the narrower question of the impact of trade on firm innovation, we do not incorporate these broader considerations.

Our paper relates to but differs from other recent surveys on trade and innovation such as Kiriyama (2012) and Shu and Steinwender (2019). While these papers concern the impacts of trade on innovation as well as firm productivity, we concentrate on the innovation effect of trade alone and provide a more elaborate coverage on this subject. We however acknowledge the importance of the linkage between trade and firm productivity and refer readers to those cited surveys for more information.[8] Moreover, in the interest of space we also exclude research on the innovation effect of FDI which is another key motor of globalization. We refer readers to related surveys such as those on FDI and technology diffusions (Saggi, 2002; Görg and Greenaway, 2004; Keller, 2004).

2. Trade and innovation

2.1 Market size effect

2.1.1 Theory

The market size effect of trade on innovation refers to the case where export opportunities incentivize innovation by enabling firms to sell and profit in a larger number of markets.[9] Several clarifications are worth making regarding our intended meaning of market size. First, it should be thought of as the size of the market faced by individual firms instead of

[8]It is worth noting that changes in firm productivity does not necessarily stem from technological innovation. For instance, a firm's productivity may rise as the result of organizational or marketing innovations, exploitation of economies of scale, etc.

[9]The market size effect therefore is consistent with the "demand-pull" theory of innovation proposed by Schmookler (1966). It is also analogous to the "scale effect" which plays an important role in endogenous growth models. See for example the discussion in Grossman and Helpman (2015).

the size of the aggregate market. This is because the return from innovation to individual firms should hinge on the residual demands they face rather than the market demand (Vives, 2008). Second, the market size we refer to is not only about the number and the income of consumers, but also involves the cost of serving each consumer which can be affected by factors such as tariffs and transportation costs. In this sense, the concept of market size is tightly related to profitability. Third, the consumers we refer to can be individuals that consume final goods or firms that purchase intermediate goods.

Conceptually, greater profitability can induce more firm innovation as many R&D projects entail a significant fixed cost and will only be worthwhile under a sizable market demand. Hence larger markets are conducive to innovation by generating sufficient profits for firms to cover the upfront cost of innovation. Moreover, this logic is expected to apply to both product and process innovations. For one thing, increased market size raises the return from product innovation by ramping-up the net value of introducing new product lines or improving the quality of existing products. For another, selling to more markets allows firms to operate on a greater scale and this ramps-up the net return from process innovation.

That said, market expansion induced by exports may affect product and process innovations to different extent. Flach and Irlacher (2018) develop a variety-expansion model and show that this can occur when the scope of product differentiation differs across industries. In the model, each firm can produce multiple varieties of a good and the degree of product differentiation is proxied by the elasticity of substitution between varieties. The authors show that better export opportunities increase both product and process innovations by domestic firms. Nevertheless, product innovation rises relatively more in industries with greater product differentiation, whereas the opposite holds for process innovation. Importantly, this pattern is driven by industry-level demand and cost linkages. The demand linkage refers to the cannibalization effect where a new variety introduced can erode the demand for existing varieties. This effect tends to be weaker in more differentiated industries where the elasticity of substitution between varieties is low. The cost linkage refers to how effectively a process innovation can be applied to production of different varieties. Such applicability is lower in more differentiated industries where alternative

varieties tend to require distinct technologies to produce. As a result, both linkages boost the relative return to product (process) innovation for more differentiated (homogeneous) products, leading firms across industries to undertake differential innovation strategies in response to export opportunities.

The returns to alternative types of product innovation may be affected by income similarity between export and domestic markets. This can occur with non-homothetic preferences under which wealthier consumers tend to value quality more. In this case, exporting to richer countries can provide direct incentives for firms to pursue quality-upgrading innovation, since the foreign consumers are willing to pay a larger premium for quality. Verhoogen (2008) develops a model of quality differentiation to demonstrate this mechanism: in his model, better access to Northern markets induces Southern firms to improve the quality of their exports to these markets. As a result, they sell higher quality goods in the North than in their domestic market. Insofar as a portion of the quality improvement arises from in-house R&D, this finding implies that quality-upgrading innovation should increase with the income levels of export destinations.

Similarity between export and domestic markets may also affect firm's incentive for process innovation. Intuitively, exporting to markets with different characteristics may require firms to provide novel products, which would not effectively increase the production scale for their existing product lines.[10] This tends to dampen the market size effect on process innovation due to weaker cost linkages across product lines. In contrast, exporting to markets of alike characteristics can make process innovation more appealing as it enables firms to expand its production scale by selling the same products to more consumers. This latter mechanism has been demonstrated in various trade models (Yeaple,

[10]For example, firms selling to countries with dissimilar preferences may need to abide by different regulatory standards. Lamy (2015, 2016) highlight such regulatory heterogeneity as a particular form of international externality that may reduce the economies of scale for firms that produce different versions of products for different markets. See Geng (2019) and Grossman et al. (2019) for analysis of how heterogeneous country preferences can lead to different national product standards.

2005; Costantini and Melitz, 2008; Desmet and Parente, 2010; Atkeson and Burstein, 2010).[11]

Last but not least, one may expect that the positive impact of exports on process innovation can increase with a smaller domestic market. The intuition is straightforward. Firms facing a limited consumer base have to operate on a restricted scale and therefore lack the incentives for improving production technology. In this case, export opportunities allow firms to substantially expand their production scale, which would significantly raise the return from process innovation.

Summary

Theory predicts a positive market size effect of exporting on innovation. The magnitude of this effect on alternative types of innovation depends on factors such as the scope of product differentiation, market similarity and relative size of domestic market. Greater product differentiation induces more product innovation relative to process innovation due to the demand and the cost linkages. Improved access to richer markets promotes quality-upgrading product innovation, while exporting to destinations with similar market characteristics augments the benefit from process innovation. Finally, the market size effect of trade on process innovation can be greater for firms based in smaller countries.

2.1.2 Empirics

Employing US data, early empirical studies find robust evidence for a positive correlation between innovation and firm size – the latter can be considered as a proxy for the market size faced by a firm. For example, Schmookler (1966) documents that firms with higher sales conduct more R&D, and he argues for a causal relationship running from the sales to

[11]While these papers draw on different models, they all highlight the mechanism that larger markets lead to bigger firms which have stronger incentives for process innovation. But the way in which the bigger firms emerge can vary across models. For example, Desmet and Parente (2010) develop an adapted Hotelling model where a larger market can sustain more incumbent firms which are also bigger in size. In the model of Atekin and Burstein (2010) with monopolistic competition and firm heterogeneity, bigger firms arise because larger markets intensify competition, forcing less productive firms to exit and reallocating their market shares to more productive firms that end up expanding in size.

the innovation effort. Pakes and Schankerman (1984) find that industry-level R&D intensity tends to increase with output growth. A few studies focus specifically on the pharmaceutical industry where R&D is pivotal, and they estimate a positive correlation between expected revenues in the target market and the entry of new drugs (Scott Morton, 1999; Reiffen and Ward, 2005; Acemoglu and Linn, 2004).

More recently, a growing number of empirical studies have found that export-induced market expansion can positively affect domestic innovation. Bustos (2011) studies the innovation effects of lowered trade barriers by examining trade liberalization within the Southern Common Market. Specifically, she estimates the innovation responses of Argentinean firms to the reductions in Brazil's import tariffs over the period of 1992-1996. Notably, the data she employs contains self-reported information which allows one to distinguish between product and process innovations. Applying the difference-in-differences approach, Bustos finds that firms in industries facing larger tariff cuts tend to perform more of both product and process innovations.

Lileeva and Trefler (2010) study a similar question but use data on Canadian firms. They examine the US-Canada Free Trade Agreement (FTA) taking effect in January 1989, which significantly reduced the import tariffs between the US and Canada. It is found that Canadian firms that were induced by the tariff cuts to begin exporting or export more increased their investment in product innovation and advanced manufacturing technologies. Their analysis does not detect statistically significant changes in process innovation. One explanation may be that Canadian firms had chosen to adopt better manufacturing technologies as opposed to developing such technologies on their own.[12]

Empirical evidence also supports the proposition that product differentiation can shape the market size effect of trade on alternative types of innovation. Flach and Irlacher (2018) test this proposition using Brazilian firm-level data over 1998-2005. They explore a largely

[12]See also Aghion et al. (2018), Lim et al. (2018) and Coelli et al. (2018) for more recent empirical evidence that new export opportunities encourage domestic innovation. These studies use the incidence of patenting to proxy firm's innovation activity but do not differentiate between alternative types of innovation.

unexpected devaluation of the Brazilian real that enhanced the access to foreign markets for Brazilian manufacturing firms. The authors find that the improved access to foreign markets raised the profits for Brazilian firms, which induced them to conduct more of both product and process innovations. Importantly, they find that the relative size of these effects depends on the scope of industry-level product differentiation: firms in differentiated industries are more likely to pursue product innovation, whereas those in homogeneous industries invest relatively more in process innovation. These patterns are consistent with their theoretical predictions outlined in the last subsection.

There also exists suggestive evidence that exporting to richer markets induces quality-upgrading innovation. Specifically, empirical trade research has established the stylized fact that firms export better quality goods to countries of higher income (Hallak, 2006; Verhoogen, 2008; Feenstra and Romalis, 2014; Caron et al., 2015). Note that this finding is not direct evidence for quality innovation as firms may achieve quality improvement through means such as hiring better educated workers (Verhoogen, 2008) or purchasing higher quality inputs (Kugler and Verhoogen, 2012). Nevertheless, it suggests that firm's choices of quality indeed respond to income levels of destination markets, and it seems implausible that such responses are independent of firm's in-house R&D.

Finally, it is worth noting that export opportunities may stimulate domestic innovation through the additional channel of learning. Particularly, exporting allows firms to acquire information and knowledge about foreign markets which can facilitate their innovation activity. As pointed out by Shu and Steinwender (2019), learning should more likely occur when firms export to developed countries which tend to have technologically more advanced buyers. Recent empirical studies suggest that export-induced learning is indeed associated with increased domestic innovation (Baldwin and Gu, 2004; Salomon and Shaver, 2005; Damijan et al., 2010; Bratti and Felice, 2012). Specifically, some of these papers find that learning is positively correlated with product innovation (Bratti and Felice,

2012), while others find that learning stimulates process innovation (Damijan et al., 2010).[13]

Summary

Empirical evidence well corroborates the market size effect of exports on innovation. Export opportunities promote overall innovation activity by domestic firms and increase at least one of product and process innovations. Industry characteristics such as the scope of product differentiation can determine the type of innovation that responds more to new export opportunities. In addition, there exists suggestive evidence that selling to richer markets creates incentives for quality-upgrading innovation by domestic firms. Finally, evidence suggests the possible learning effect of exporting which can facilitate domestic innovation in conjunction with expanded market scope.

2.2 Competition effect

2.2.1 Theory

While international trade can expand the market size available to firms, it may also intensify market competition through the channels of exports and imports. On one hand, export opportunities can increase domestic market competition by encouraging entry of local firms. This mechanism has been illustrated in trade models such as Melitz and Ottaviano (2008), Desmet and Parente (2010) and Aghion et al. (2018). On the other, imports may increase domestic market competition by inducing the entry of foreign firms. It is also worth noting that much of the literature examines the relationship between competition and innovation without assuming that the competition is necessarily induced

[13]Aw et al. (2011) quantify the learning effect of export on R&D using data on Taiwanese electronics industry. They adopt a structural approach which allows for counterfactual analysis of the impact of exogenous changes in market size. One advantage of their approach is that it allows for separately quantifying the market size and the learning effects of trade. Their model predicts that an exogenous market expansion induces more firms to conduct R&D only when such investment can lead to future improvement in productivity. This insight is intuitive and echoes the management literature that highlights the vital role of innovation in determining a firm's competitive position. The paper also finds that market expansion induces relatively less R&D investment if learning-by-exporting is shut down, suggesting the presence of a positive learning effect. Specifically, when learning is not possible, the proportion of R&D-performing firms after market expansion would increase by 28% and 15% less in two and fifteen years respectively.

by trade. Hence, this section will discuss relevant studies regardless of the source of market competition.

Theoretically, competition can affect innovation in both directions. On one hand, competition may dampen innovation by restricting firm size. The reason is that smaller firms tend to have less stable platform for innovative activity and enjoy weaker economies of scale in R&D (Schumpeter, 1942; Aghion and Howitt, 1992). On the other hand, Arrow (1962) argues that a monopolist facing limited competition may have less incentives for R&D due its high pre-innovation rents. In this case, competition can encourage innovation by lowering such rents and raising the incremental returns from innovation. Notably, Gilbert (2006) points out that Arrow's argument applies best to process innovation, that is, a monopolist can still have strong incentives for product innovation. For example, a monopolist may want to expand its product portfolio via product innovation, which enables it to extract more consumer surplus through price discrimination. Gilbert then hypothesizes two conditions under which competition is likely to foster product innovation: (i) there is intense competition for the old product; (ii) innovation is drastic such that it renders the old product obsolete.

Gilbert's argument alludes to a potential role of industry structure in shaping the effect of competition on industry-level innovation. Aghion et al. (2005) investigate this mechanism by differentiating between two types of industries: neck-and-neck (NN) and leader-and-laggard (LL). An NN industry is characterized by low pre-innovation rents due to tight competitive positions of the incumbents.[14] As a result, rising competition in NN industries promotes product innovation by which firms can leave behind their rivals. Such a mechanism is often labeled as the "escape-competition effect". In contrast, an LL industry features high pre-innovation rents as the technological gap between leaders and laggards is substantial. In this case, stronger competition discourages product innovation by the laggards via reducing their post-innovation rents. This mechanism is also termed as the "Schumpeterian effect". Moreover, the interactions of these two effects lead to an inverted-

[14]In particular, Aghion et al. (2005) model the degree of product market competition as the likelihood of collusion between firms.

U relationship between the level of economy-wide competition and the aggregate innovation rate.

Theoretical analysis also highlights the role of demand characteristics in shaping the impact of competition on product innovation. A seminal contribution in this respect is Dhingra (2013) who develops an open-economy model where each firm produces a brand that may consist of multiple varieties, with product innovation increasing the number of varieties under a brand. A key insight yielded by the model is that the effect of import competition on product innovation depends crucially on consumer preferences for brand size/visibility.[15] When these preferences are weak, competition intensifies within-brand cannibalization and leads firms to reduce product innovation for maintaining fewer product lines. When these preferences are strong, by contrast, competition can lead to more product innovation as the benefit from enhancing one's brand size dominates the negative cannibalization effect. An important implication of these findings is that product innovation may respond to competition distinctly across industries with varying demand characteristics.

Competition may promote innovation by inducing reallocation of resources toward innovative activity. Several mechanisms underlying this proposition have been formulated. First, Holmes and Schmitz Jr. (2001) demonstrate that the pressure from import competition may force domestic incumbents to switch from unproductive activities such as blocking the entry of new technologies to R&D.[16] Second, the agency literature shows that managers may exert suboptimal effort by maximizing their private benefits rather than profits (Hart, 1983; Schmidt, 1997; Vives, 2008; Raith, 2003). In this case, increased competition can incentivize managers to modify their behavior by investing more in R&D. Third, Bloom et al. (2019) show that stronger competition may reduce the returns to certain "trapped" factors within firms which are too costly to deploy for alternative purposes. As

[15]For example, brand size/visibility can be valuable to consumers if they face high search costs. See Bronnenberg et al. (2012) for recent empirical evidence.

[16]It is worth noting that in their model, falling foreign tariffs can lead domestic incumbents to substitute R&D for blocking. The model therefore also predicts a positive market size effect of exporting on innovation.

the returns to these factors drop, their opportunity costs fall so that firms become more willing to use them as inputs for innovation.

Finally, firms' innovation responses to competition may hinge on their productivities relative to others. Boone (2000) develops an oligopoly model with heterogeneous firm productivity and shows that as competition rises, product innovation increases for high-productivity firms but decreases for low-productive ones. In contrast, process innovation falls for the most and the least productive firms but rises for those with intermediate levels of productivity. Notably, Boone shows that at the industry level, competition cannot increase both product and process innovation. Dhingra (2013) considers specifically import competition and finds that it differentially affects innovation decisions by domestic exporters. In particular, high-productivity exporters cut product innovation as they face the toughest competition from foreign firms. In contrast, low-productivity exporters increase product innovation as the least productive domestic firms exit the market. Despite this, all domestic exporters reduce process innovation due to their shrinking market shares.[17]

Summary

Theory suggests that competition can affect domestic innovation in both directions. An overarching insight is that competition encourages innovation provided it raises the incremental returns from innovation. Competition is more likely to increase such incremental returns, especially from product innovation, when industries are neck-and-neck, consumers sufficiently value brand size, or firms underuse innovation resources, etc. In addition, firms with heterogeneous productivities tend to respond differently in their innovation strategies to changing degrees of competition.

2.2.2 Empirics

[17]In addition, endogenous growth models with firm heterogeneity predict a positive effect of competition on process innovation through market selection (see, for example, Denicolò and Zanchettin, 2009; Impullitti and Licandro, 2018). In these models, increased competition forces less productive firms out of the market, expands the market scale for more productive firms and enhances their incentives for process innovation.

As with the theoretical literature, empirical research on competition and innovation yield mixed findings. Gilbert (2006) provides an extensive list of earlier empirical studies that examine competition in general (i.e. not necessarily induced by trade) and the evidence is altogether inconclusive.[18] More recent studies generate some new insights, such that the effect of competition on domestic innovation can be country-dependent. Specifically, studies using the U.S. data largely find a negative effect of competition on domestic innovation. Examples include Hashmi (2013) who analyzes a sample of the U.S. public firms as well as Goettler and Gordan (2011) who examine the U.S. computer microprocessor industry. In contrast, Aghion et al. (2005) employ the U.K. data and identify an inverted-U shape relationship between competition and innovation.[19]

The geographic variations in the innovation effect of competition has been further corroborated by a growing empirical literature that examines specifically import-induced competition. First, the literature finds that innovation in Europe responds positively to import penetration. For example, Blundel et al. (1999) estimate a dynamic model of innovation using data on firms listed on the London International Stock Exchange. They find that stronger import competition promotes industry-level innovation, as measured by the total number of patents granted in an industry. More recently, Bloom et al. (2016) study the impacts of Chinese import competition on firm innovation and productivity in twelve European countries. They find that the absolute volume of innovation, proxied by the number of patents granted, increases within firms that have greater exposure to lowered trade barriers to Chinese imports.

When it comes to developing countries, research also identifies a largely positive effect of import competition on domestic innovation. Employing survey data on Mexican plants for the years of 2002 and 2004, Teshima (2009) finds that import competition induces Mexican plants to increase their total R&D investments. Gorodnichenko et al. (2010) explore survey

[18]See Table 6.2 of the paper. These studies also suggest that the effect of competition on innovation may be heterogeneous across industries.

[19]The inverted-U relationship between competition and innovation is also documented in early studies such as Scherer (1967) and Kamien and Schwartz (1972).

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data on firms in twenty-seven transition economies and estimate that conditional on markups, firms that perceive a greater pressure of foreign competition have a larger likelihood of carrying out R&D. Fernandes and Paunov (2013) and Medina (2020) find respectively that Chilean and Peruvian firms pursue more quality upgrading when facing tougher import competition. It is worth noting that the evidence from developing countries is not uniformly positive. For instance, Dang (2017) examines the innovation impact of Chinese import competition on Vietnamese firms over 2011-2015. The author finds no evidence that rising imports from China affects innovation or technology adoption by Vietnamese firms. Lim et al. (2018) examine Chinese firm-level data over 2000-2006 and find that stronger import competition reduces aggregate patenting and R&D investment by Chinese manufacturing firms.

By contrast, studies about North America find that import competition weakly dampens domestic innovation. Autor et al. (2019) assess the effects of Chinese imports on the performance of publicly listed US firms. They find that increased Chinese imports lead the US firms to reduce R&D investment and produce less patents. Moreover, this occurs along with the worsening of various performance measures for the US firms, including local and global sales, book and stock values, and purchases of labor and capital inputs. On the other hand, Xu and Gong (2017) find that import competition has no significant impact on aggregate R&D expenditures by US firms.[20] Kueng et al. (2017) examine Canadian survey data and find that import competition from China reduces both product and process innovations by Canadian firms.

The above empirical findings raise the important question as to why the innovation effect of import competition differs across countries. As pointed out by Shu and Steinwender (2019), such an empirical pattern is consistent with alternative theories outlined in the last subsection. First, it may be due to differences in industry structure across countries -

[20]Hombert and Matray (2018) also use the US firm-level data but explore the role of R&D in moderating the negative innovation effect of import competition. They find that firms that conduct more R&D ex ante experience less fall in sales and profits when facing increased Chinese imports. They provide evidence that investing in R&D allows firms to increase product differentiation which helps them attenuate the negative impact of import competition.

industries in North America may feature large technological gaps between leading and lagging firms, whereas industries in Europe and certain developing countries are more neck-and-neck. Author et al. (2019) present some preliminary evidence for the US industries to be of the LL type. Second, firms in developing countries may have less managerial capabilities and thus suffer from more severe managerial slack. Third, developing countries are more likely to have the problem of "trapped-factor" due to their higher market frictions.[21] That being said, it remains an open question regarding the relative importance of these alternative mechanisms in driving the geographic differences in innovation responses to import competition.

It is worth noting that some of the above studies have detailed information on the nature of innovation and can therefore shed light on how import competition may affect different types of domestic innovation. For example, Teshima (2009) finds that import competition increases process rather than product innovation by Mexican firm. By contrast, Gorodnichenko et al. (2010) estimate that firms in the twenty-seven transition economies conduct more of both product and process innovations as they perceive greater foreign competition. Given import competition reducing innovation in Canada, Kueng et al. (2017) find that the contraction is larger for process than for product innovation. Overall, existing evidence is preliminary but appears to suggest that process innovation is more responsive to import competition than product innovation.

The findings we have discussed so far concern the average effect of import competition on domestic innovation. There exists ample evidence that individual firms may adapt their innovation strategies differently to import competition. The overall picture is that initially better performing firms lose less or advance more in innovation when facing tougher import competition. For instance, Autor et al. (2019) show that the contraction in patenting caused by import competition is smaller for the US firms that have greater initial capital per employee, higher initial rate of return on investment, or larger initial debt/equity ratio.

[21]Medina (2020) concludes that her findings about Peruvian firms are consistent with the mechanism that competition in low-quality segments presses firms to reallocate their idle specific factors towards the production of high-quality varieties.

Xu and Gong (2017) find that the US firms with higher initial productivities increase R&D investment in the presence of stronger import competition, but those with lower productivities conduct less R&D. In addition, Gorodnichenko et al. (2010) find that firms closer to the technology frontier conduct more innovation under tougher import competition, whereas those far from the frontier reduce their innovation.

Summary

Although empirical studies remain inconclusive about the relationship between import competition and innovation, there are several patterns emerging from the literature. First, the innovation impact of import competition varies across regions, being largely positive for Europe and developing countries but weakly negative for North America. This is consistent with multiple theoretical mechanisms although it remains unclear which of them are at work. Second, there is some suggestive evidence that process innovation tends to be more responsive to import competition than product innovation. Third, the impact of import competition on innovation is heterogeneous across firms and tends to be in favor of those that are initially more competitive.

2.3 Import of intermediate inputs

2.3.1 Theory

Import of intermediate inputs, also known as foreign sourcing, has become increasingly prevalent as the result of trade liberalization. For example, empirical studies document that firms may import a greater variety of inputs as they face lower tariff barriers (Feenstra, 1994; Broda and Weinstein, 2006; Arkolakis et al., 2008). Furthermore, expanded access to foreign inputs can raise the productivities of importing firms, as demonstrated in trade models such as Ethier (1982) and Markusen (1989).

Although foreign sourcing can promote productivity growth, its impact on innovation is theoretically ambiguous. On one hand, input imports can be complementary to domestic innovation for multiple reasons. First, access to foreign inputs can bring about knowledge spillovers that may facilitate R&D activity by the importing firms. Second, foreign

sourcing may reduce production cost by allowing firms to purchase cheaper intermediate inputs. This in turn can raise the return from product or process innovation. Third, it is well-recognized that absorptive capacity plays a key role in technology adoption (Cohen and Levinthal, 1990). Hence, firms that source internationally may have stronger incentives to improve their absorptive capacity through R&D. On the other hand, foreign sourcing can also have a substitution effect on domestic innovation. For example, foreign sourcing allows firms to acquire cheaper and better inputs from outside, which may replace in-house innovation of such inputs (Liu and Qiu, 2016).

Summary

Theory predicts that import of intermediate inputs can both complement and substitute domestic innovation. The net effect of foreign sourcing on domestic innovation should depend on the relative strength of the two forces.

2.3.2 Empirics

Empirical research on foreign sourcing and innovation is still at its infancy, but most existing studies find evidence that foreign sourcing promotes domestic innovation.[22] Goldberg et al. (2010) estimate the effect of improved access to foreign inputs on the introduction of new products by Indian manufacturing firms. Their data covers the period of 1989-2003 during which India's trade liberalization substantially lowered its import tariffs on intermediate inputs. They find that reductions in Indian input tariffs contribute to 31 percent of the new products introduced by domestic firms, and much of this effect is attributed to the new inputs imported from foreign suppliers. This would suggest a positive effect of foreign sourcing on domestic product innovation insofar as certain new products are created through R&D.

[22]A large body of empirical work has documented a positive effect of foreign sourcing on the productivity of domestic firms. See for example, Halpern et al. (2005), Amiti and Konings (2007), Kasahara and Rodrigue (2008), Goldberg et al. (2010), Topalova and Khandelwal (2011). These studies however do not directly address the linkage between foreign sourcing and innovation.

Bøler et al. (2015) explore the synergies between foreign sourcing and R&D using data on Norwegian manufacturing firms over 1997-2005. They estimate a structural model that features interactions between a firm's import of inputs and its R&D decisions, with the latter pertaining to either product or process innovations. On one hand, access to foreign inputs encourages innovation by domestic firms as it can lower production cost and thus increase the return to R&D. On the other hand, R&D improves future profit flows, which in turn ramps-up the return from foreign sourcing. Simulation of the model shows that foreign sourcing accounts for one-fifth of the revenue growth among firms that are new R&D performers, indicating that firms importing inputs conduct more innovation.

Chen et al. (2017) investigate the role of knowledge spillovers in the linkage between foreign sourcing and domestic innovation. They develop a model where foreign sourcing by firms facilitates their knowledge accumulation which helps lower their R&D cost. The model is tested with Chinese firm-level data over 2000-2006. It is found that improved access to foreign inputs raises the R&D intensity of Chinese firms calculated as the ratio of a firm's annual R&D expenditures to its annual sales or total assets. Moreover, they find evidence that such an effect is driven by knowledge diffusion. Specifically, they show that the positive effect of foreign sourcing on innovation is stronger in cases where expected technology spillovers are greater. These include intermediate inputs coming from high-income countries or importing firms being high-tech or private.

On the other hand, there is evidence that foreign sourcing can discourage domestic innovation. A seminal study on this front is Liu and Qiu (2016), who examine Chinese data over 1998-2007 during which China reduced its input tariffs significantly following the entry into the WTO. Unlike Chen et al. (2017) who focus on the input side of innovation (i.e. R&D intensity), they look at innovation output as measured by the number of patent applications. It is found that foreign sourcing reduces patent filings by Chinese firms, and this effect is robust to a variety of estimation specifications. Their results thus suggest the existence of the substitution effect of foreign sourcing on domestic R&D.

Empirical research also documents that the effect of foreign sourcing on innovation is more significant for firms with better performance. Goldberg et al. (2010) find that Indian input tariff reductions increase domestic R&D but this only occurs to initially large firms. Bas and Berthou (2017) develop a monopolistic competition model of trade with heterogeneous firm productivities. In their model, firms can purchase inputs from domestic and foreign suppliers, but technology that affects production cost is biased toward foreign inputs. The model predicts that input tariff reductions lower the productivity cutoff for firms to adopt advanced technology. Given that initially most productive firms already operate under high-level technologies, foreign sourcing ends up inducing firms with mid-range productivities to upgrade technology. They further test the model with data on Indian firms over 1999-2006 and find support for their model predictions. Finally, Liu and Qiu (2016) find that the negative impact of foreign sourcing on domestic innovation is larger for firms with initially higher capital intensity or more advanced technologies.

Summary

Empirical evidence suggests that imports of intermediate inputs can either complement or substitute domestic innovation. In the former case, there is evidence that domestic innovation increases due to knowledge diffusion induced by foreign sourcing. There is also robust evidence that the innovation effect of foreign sourcing can be heterogeneous across firms. Specifically, sourcing internationally appears to have a greater impact on firms of medium to large size or productivity regardless of the direction of the impact.

4. Conclusion

This paper reviews the theoretical and empirical economic literature regarding the effect of trade liberalization on innovation. We highlight three main channels through which trade can affect innovation incentives for domestic firms. These are expanding market size, intensifying market competition, and facilitating foreign sourcing. Given the current findings, it is safe to conclude that the market size effect of trade on innovation is positive, whereas competition and foreign sourcing can affect domestic innovation in both directions. This indicates that the overall impact of international trade on a country's aggregate

innovation can be ambiguous and would depend on the relative magnitude of these effects. In fact, this verdict holds water even when one looks at the innovation effects of exporting and importing separately. Specifically, better export opportunities encourage domestic innovation through the market size effect but may also dampen it by intensifying domestic competition. These opposing effects can also be expected from falling barriers to imports which result in tougher import competition and more foreign sourcing.

A number of practical implications can be drawn from the lessons we have learned about the complex nexus between trade and innovation. Here we discuss a few of them. First, existing evidence appears that exports are more likely to foster domestic innovation relative to imports. This could provide a further justification for export-oriented industrialization that has been adopted by many countries. Particularly, such an industrial policy not only can lead to capital accumulation by implementing countries, but also may promote knowledge accumulation by increasing domestic innovation. Second, the lesson that international trade can pose both opportunities and challenges for innovating firms suggests a potentially more critical role of government intervention in R&D activity (Scuotto et al., 2020). Interestingly, this perspective is consistent with the institutional arrangements of the World Trade Organization, under which various trade policy instruments are prohibited whereas R&D subsidies are permitted. Third, the increasingly globalized markets faced by firms may call for adjustment in international coordination over intellectual property policy.[23]

Looking forward, we see ample room for further research. First, we need to know more about the three discussed channels through which trade affects innovation. For example, as for the market size effect, there remains scarce direct evidence on how exporting to dissimilar markets may incentivize different types of innovation. Regarding the competition effect, more empirical evidence is needed to distinguish between alternative theoretical mechanisms that have been proposed. Particularly, it is important to identify the

[23]See for example Geng and Saggi (2015, 2020) who analyze how trade liberalization may affect the welfare implications of national treatment in intellectual property protection, a key principle of the Agreement on Trade-Related Aspects of Intellectual Property Rights administered by the WTO.

mechanisms underlying the geographical differences in how domestic innovation responds to import competition. In addition, literature generally treats import-induced competition identical to other types of competition such as that arising purely from domestic markets. It seems worthwhile to sort out the nuances between competition triggered by trade and non-trade factors as well as their potentially differential impacts on innovation. Finally, there lacks systematic evidence on the innovation effect of foreign sourcing and the conditions that determine the direction of the effect.

Second, the literature has predominantly focused on product and process innovations. Future research could examine how trade may affect firm innovation based on alternative categorizations. For example, it is well-known that innovation can be of Schumpeterian Mark I and Mark II types (Nelson and Winter, 1982; Kamien and Schwartz, 1982). Loosely speaking, the former represents path-breaking innovations by entrepreneurial entrants that can lead to "creative destruction" of the rents for the incumbents, whereas the latter refers to cumulative innovations by incumbents along established technological trajectories. Research shows that how likely each of the two types of innovation arises can depend on the nature of technology which differs across industries (Malerba and Orsenigo, 1996; Breschi et al., 2000). Moreover, industries featuring Schumpeterian Mark I and Mark II innovations can evolve into each other (Klepper, 1996; Christensen and Rosenbloom, 1995). In our view, more work is called for about the role of international trade in the Schumpeterian theory of innovation. Particularly, research along this line may help shed light on the geographic differences in firm's innovation responses to import competition.[24]

Third, more needs to be known regarding the impact of trade on organizational, managerial and marketing innovations. This is an important area of research because not only can these alternative modes of innovation directly shape the competitive edges for firms, they may also interact with firm's technological innovation. For example, business literature has long

[24]In addition, innovation can also be categorized as basic or applied, and the former is more likely under-provided due to its potentially large positive externalities on future innovation and productivity. It is therefore important to understand whether trade may lead to greater incentives for firms to pursue basic research. Existing evidence such as in Liu and Rosell (2013) suggests that this is not the case when imports intensify competition in the domestic market. Further research is needed to shed more light on this issue.

recognized that organizational innovation can lead to technological innovation, as it entails more open organizational structure and practices for new ideas to be generated and implemented (Damanpour and Evan, 1984; Damanpour et al., 1989; Azar and Ciabuschi, 2017). This implies that trade is likely to induce firms to engage in organizational innovation prior to investing in R&D. In any case, the linkages between trade and various non-technological forms of innovation appear a promising avenue of research.

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