Centre for Economic Performance

Discussion Paper ISSN 2042-2695

No. 2203
August 2026

Dynamic effects of trade

Benny Kleinman
Ernest Liu
Stephen J. Redding

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

UKRI Economic and Social Research Council

Abstract
The existence of aggregate welfare gains from trade is one of the classic insights from international economics. However, these conventional welfare gains are static, in the sense that they take existing factor supplies and production technologies at a point in time as given. Recent research has highlighted dynamic effects of trade through endogenous factor accumulation and technological innovation over time, although there remains less consensus about the quantitative magnitude of these dynamic effects than about their static counterparts. Key insights from this research are that short-run and long-run responses to trade liberalization differ; capital accumulation amplifies the impact of international trade shocks; trade can facilitate technology adoption and the diffusion of ideas by changing the composition of suppliers; effects on lifetime welfare differ substantially from those on steady-state welfare, once transition dynamics are taken into account; and market failures can either magnify the overall welfare gains from trade or rationalize activist trade and industrial policies.

Keywords: capital accumulation; economic growth; innovation; international trade
JEL codes: F14; F15; F50

This paper was produced as part of the Trade Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

We are grateful to Princeton and Stanford Universities for research support. This paper was commissioned for the Journal of Economic Perspectives. We would like to thank Philippe Aghion, Chad Jones, Pete Klenow, Jeffrey Kling, Jonathan Parker, Tim Taylor, Chris Tonetti and Heidi Williams for helpful comments. The usual disclaimer applies.
Benny Kleinman, Stanford University and NBER. Ernest Liu, Princeton University and NBER. Stephen J. Redding, Stanford University, NBER, CEPR and Centre for Economic Performance at the London School of Economics.

Published by
Centre for Economic Performance
London School of Economic and Political Science
Houghton Street
London WC2A 2AE

1 Introduction

The existence of aggregate welfare gains from trade is one of the classic insights from the field of international economics. Opening a closed economy to trade acts like an improvement in technology. In a closed economy, each country has to produce all the goods that it consumes. In contrast, in an open economy, countries can instead specialize in the goods that they are relatively more efficient at producing, and sell those goods on world markets, in order to obtain other goods that they are less efficient at producing. This insight of specialization according to comparative advantage implies that international trade is not zero-sum, but is instead positive-sum. Therefore, countries experience mutual welfare gains from trading with one another. However, these aggregate welfare gains are static, in the sense that they take a country's factor supplies (including physical capital) and production technology at a point in time as given.

The last two decades have seen the development of a great degree of consensus about the quantitative magnitude of these static welfare gains. Researchers have developed a class of models that feature a gravity equation for bilateral trade between countries, in which trade flows decline with trade costs with a constant elasticity, and depend on exporter and importer size. In this class of models, the static welfare gains from trade can be computed using two sufficient statistics: the share of a country's expenditure on its own goods in the open economy (the domestic trade share) and the constant elasticity of trade flows with respect to trade costs (the trade elasticity). The domestic trade share is directly observed in the data. The trade elasticity can be estimated using the gravity equation and data on bilateral trade flows and costs.

A large number of studies have implemented this approach for many different countries and time periods. For large countries, such as the United States, which have high expenditure shares on their own goods, these static welfare gains from trade are relatively modest. From the review in Costinot and Rodríguez-Clare (2018), these static welfare gains range from 2-8 percent of real income per year for the United States, depending on the assumed the trade elasticity.

Although the baseline specification in this class of models assumes a single sector and a single factor of production (labor), researchers have considered a variety of extensions and generalizations. If there are many industries, with low trade elasticities in some industries and low substitutability across industries, the static welfare gains from trade can become substantially larger than implied by single-sector models. For example, if oil is a critical input for modern economies, and a country does not have its own natural endowments of oil, there are large welfare gains from importing oil. Additionally, if these multiple industries are connected by input-output networks, international trade costs are incurred not only when final goods are shipped abroad, but also each time an intermediate input crosses a national border. Therefore, the more times that parts and components cross international borders as part of a global value chain (GVC), the larger the welfare gains from reductions in international trade costs.

More generally, another line of research in the growth literature suggests that by taking factors of production and technology at a point in time as given, these conventional static welfare gains abstract from important dynamic effects of international trade through factor accumulation and endogenous technological change over time. Three broad mechanisms for these dynamic welfare effects can be distinguished. First, trade liberalization can affect the incentive to accumulate factors of production, such as physical capital. Second, trade liberalization can influence the pace and direction of technological change, whether through serendipitous learning by doing as a by-product of production, or through intentional investments in innovation. Third, trade liberalization can affect the selection of heterogeneous firms that supply a country's market, which in turn influences innovation, technology adoption, and the diffusion of ideas across these heterogeneous producers. While there is broad agreement about the potential economic relevance of these dynamic welfare effects of trade, there is much less consensus about their quantitative magnitude than for the conventional static welfare gains from trade.

In many static trade models, the market equilibrium is efficient, in the sense that it is impossible to reallocate resources in the world economy without making someone worse off. Although individual countries can have incentives to manipulate relative prices (the terms of trade) on world markets, the free trade equilibrium coincides with the social optimum that would be chosen by a global planner under some Pareto weights on the representative agent in each country. Since consumption and production in the free trade equilibrium are chosen optimally for a small country that cannot influence world prices, small changes in trade frictions have only second-order effects on welfare. In contrast, many dynamic models of international trade feature externalities and market failures, such that the free trade equilibrium is inefficient. For example, models of endogenous technological change often feature monopoly profits for successful innovators, and externalities from knowledge spillovers. As a result, consumption and production in the free trade equilibrium are no longer socially optimal, and small changes in trade frictions can have first-order effects on welfare.

These market failures in dynamic trade models have two sets of conflicting implications. On the one hand, they imply that the dynamic welfare gains from trade can be large relative to the static welfare gains from trade in some circumstances. This possibility arises when trade liberalization reallocates resources in a way that mitigates these other distortions, with first-order effects on welfare. For example, in an influential study of Brexit in the United Kingdom, the dynamic effects of trade were estimated to approximately double the overall welfare losses relative to the conventional static effects of trade (Dhingra et al., 2017). On the other hand, they imply that protectionist trade and industrial policies can be welfare improving in other circumstances. This possibility arises when trade liberalization exacerbates these other distortions, and protectionist policies are required to mitigate their impact. For example, China's industrial policies potentially could be justified in these terms (e.g., Liu 2019, Barwick et al. 2025). Determining which of these two possible cases applies can impose strong information requirements on a policy maker. Even when protectionist trade and industrial policies are justified, they need not take the form of tariffs, which distort the prices faced by both producers and consumers, but may rather take the form of production subsidies, which only distort the prices faced by producers.

The magnitude of these dynamic effects of trade depends critically on whether the opening of trade permanently affects the economy's growth rate (as in models of "endogenous growth") or only affects the economy's growth rate along the transition path to steady-state (as in models of "semi-endogenous growth"). Even policies that have small permanent effects on growth can have large impacts on welfare, as higher growth rates compound over time. In the famous words of Lucas (1988), once one starts to think about such growth effects, "it is hard to think about anything else." In models in which growth effects are temporary and a steady-state level of economic activity exists, physical capital accumulation and endogenous innovation can magnify the impact of trade on steady-state welfare relative to the welfare gains from trade in static models. However, the accumulation of additional physical capital and technological knowledge must be paid for by lower consumption along the transition path towards steady-state. Furthermore, this factor accumulation occurs gradually over time, with the result that the higher steady-state levels of welfare must be discounted for the time taken to converge to steady-state.

We focus on international flows of goods rather than those of capital and ideas, because the greatest consensus has been achieved about the quantitative magnitude of the static welfare gains from trade in goods. However, we discuss how openness in capital markets and international knowledge spillovers affect the welfare effects of trade in goods. The globalization of the world economy that occurred in the late-20th and early-21st centuries took place through a combination of increased integration in the markets for goods, capital and ideas.

We begin in Section 2 by reviewing the conventional consensus about the quantitative magnitude of the static welfare gains from trade. In Section 3, we discuss dynamic welfare gains from capital accumulation in neoclassical growth models. In Section 4, we consider learning by doing as a source of endogenous technological change. In Section 5, we turn to intentional investments in innovation as another source of endogenous technological change. In Section 6, we examine the selection of heterogeneous firms within markets and its impact on innovation, technology adoption, and the diffusion of ideas. Section 7 distills potential lessons for trade and industrial policy. Section 8 summarizes our conclusions.

2 Static Gains from Trade

A major breakthrough in the field of international trade in recent decades has been the development of quantitative trade models. These models are sufficiently rich to capture key features of the data, such as many asymmetric countries, and a realistic geography of bilateral trade costs. Despite this richness, these models remain tractable and amenable to a theoretical analysis of their properties, including the existence and uniqueness of the equilibrium, and the comparative statics of the global economy in response to shocks. In contrast to earlier computable general equilibrium (CGE) models, these quantitative trade models typically have only a small number of structural parameters to estimate. Therefore, they lend themselves to credible estimation of these parameters using exogenous sources of variation. Since these quantitative trade models rationalize the observed data on bilateral trade and income as an equilibrium outcome, they can be used to undertake counterfactuals for changes in trade policies between particular pairs of countries.

2.1 Constant Elasticity Trade Models

An especially influential class of these quantitative trade models is those that feature a gravity equation for bilateral trade flows, in which the trade elasticity (the elasticity of bilateral trade with respect to bilateral trade costs) is a constant parameter, as characterized in Arkolakis et al. (2012). Within these constant elasticity trade models, the welfare gains from opening the closed economy to international trade can be summarized by two sufficient statistics. The first is the constant trade elasticity (θ), which can be estimated using the gravity equation and data on bilateral trade and bilateral trade costs.[1] The second is the domestic trade share (the share of a country's expenditure on its own goods) in the open economy (S_{nn}^{O}), which can be calculated using observed expenditure data. Given these two sufficient statistics, welfare in the open economy ($\mathbb{W}_n^O$) relative to welfare in the closed economy ($\mathbb{W}_n^A$) for each country n can be calculated as:

$$\frac{\mathbb{W}_n^O}{\mathbb{W}_n^A} = \left(\frac{1}{S_{nn}^O}\right)^{\frac{1}{\theta}}, \tag{1}$$

where the domestic trade share in the closed economy is equal to one ($S_{nn}^A = 1$).

Since the domestic trade share in the open economy is less than one ($0 < S_{nn}^O < 1$), there are welfare gains from trade ($\mathbb{W}_n^O / \mathbb{W}_n^A > 1$). In the closed economy, each country can only consume its own good. In contrast, in the open economy, each country also has access to other countries' goods, which are imperfect substitutes. Intuitively, the smaller the share of a country's expenditure that it devotes to domestic goods in the open economy (the lower S_{nn}^O), the more attractive

[1] Outside this class of quantitative trade models, the trade elasticity can be variable, as examined in Melitz and Redding (2015) and Adão et al. (2026).

are foreign goods relative to domestic goods, and the greater is the welfare gain from having access to those foreign goods (the higher $\mathbb{W}_n^O/\mathbb{W}_n^A$). Opening the closed economy to trade operates like an improvement in production technology, because each country gains access to an improved technology for consumption. Instead of only having to consume its own good, it can consume the goods produced by many countries, which are imperfect substitutes.[2]

2.2 Quantitative Results

Empirical implementations of this sufficient statistics approach find relatively modest static welfare gains for large countries with high open-economy shares of expenditure on their own goods. For the United States, a central estimate is from 2-8 percent of real income for the United States in Costinot and Rodríguez-Clare (2018), as discussed above. Nevertheless, these static welfare gains can be substantial for small countries that have much lower open-economy shares of expenditure on their own goods. For example, for a small open economy such as Belgium, estimates can range up to around 50 percent of GDP, as discussed in Costinot and Rodríguez-Clare (2014).[3]

In evaluating quantitative trade models, it is challenging to find real-world examples of countries moving from autarky to open trade against which to compare these theoretical predictions. But there are two natural experiments from history that approximate these conditions. The first is Japan's opening to trade in the mid-19th century following the arrival of Commodore Perry in Tokyo Bay. Using data from this episode, Bernhofen and Brown (2005) estimates a welfare gain from opening trade of 8-9 percent. The second is the United States in the early-19th century, when Congress imposed a nearly complete embargo on international trade at the request of President Thomas Jefferson. Using evidence from this incident, Irwin (2005) estimates a welfare cost from closing trade of 5 percent of gross national product (GNP). Although the economy today differs in many ways from that in the 19th century, this evidence from these natural experiments aligns in broad magnitude with the predictions of this class of quantitative trade models.

Therefore a good deal of consensus has been achieved about the quantitative magnitude of the static welfare gains from trade, holding factor supplies and production technologies constant. Nevertheless, the degree of consensus should not be overstated. Estimates of the trade elasticity (θ) range widely from 2-12, which substantially affects the magnitude of the implied welfare gains from trade in equation (1). Even in static settings, it is well understood that there are mechanisms that can magnify the welfare gains from trade, as noted above. If there are many industries, with low trade elasticities in some industries and low substitutability across industries, the welfare gains from trade can become substantially larger. If these industries are connected by input-output

[2] For further analysis of this analogy between the static welfare gains from trade and an improvement in production technology, see Costinot and Werning (2023) and Costinot and Werning (2026).

[3] See Costinot and Rodríguez-Clare (2014), Costinot and Rodríguez-Clare (2018) and Caliendo and Parro (2022).

linkages, trade costs are incurred on both final goods and intermediate inputs, thereby further amplifying the welfare gains from trade liberalization.[4] Despite these caveats, the degree of consensus over the quantitative magnitude of the static welfare gains from trade is far larger than for the dynamic welfare gains from trade discussed in the ensuing sections.

3 Capital Accumulation

A natural source of dynamic effects of international trade is physical capital accumulation. The canonical framework for thinking about capital accumulation and growth is the neoclassical growth model of Ramsey (1928), Solow (1956) and Swan (1956).

3.1 Closed-economy Neoclassical Growth Model

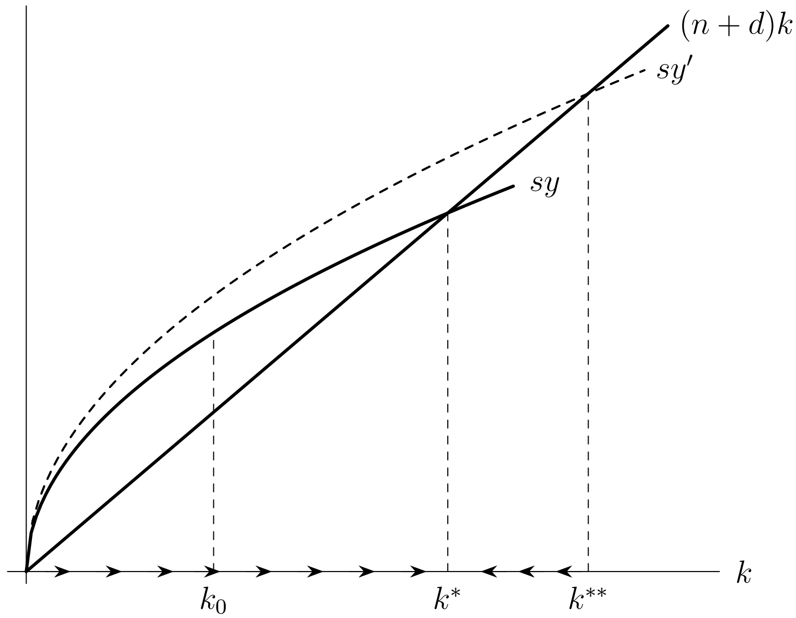
In the textbook version of this model, goods and capital markets are both closed. Each country produces output of a single final good (Y) using a constant returns to scale production technology in labor (L) and capital (K). Holding labor input constant, this production technology implies diminishing marginal returns to additional units of capital. These diminishing marginal returns imply that capital accumulation alone cannot sustain long-run growth. Instead, each country converges towards a steady-state level of the capital-labor ratio and income per capita. In Figure 1, we illustrate the determination of this steady-state capital-labor ratio in the closed-economy neoclassical growth model. We denote the capital-labor ratio by $k = K/L$ and output per capita by $y = Y/L$. We assume a constant saving rate (s) out of income, a constant rate of depreciation of capital (d), and a constant exogenous rate of population growth (n).[5] The assumption of a constant saving rate implies that the increase in the economy's stock of capital per person as a result of saving can be shown by the solid curve sy, which has a decreasing slope because of diminishing marginal returns to capital. The assumption of constant rates of population growth and depreciation implies that the decrease in the economy's stock of capital per person as a result of population growth and depreciation can be shown by the solid straight line $(n + d)k$.

For low initial levels of capital (such as k_0), the marginal product of capital is high, and the increase in the capital stock per person from saving exceeds the decline in the capital stock per person from population growth and depreciation, thereby leading to capital deepening (a rise in the capital stock per person), as shown by the arrows on the horizontal axis. For high initial levels of capital, the converse is true, which leads to capital widening (a fall in the capital stock person as

[4] See for example Yi (2003), Caliendo and Parro (2015), and Ossa (2016).

[5] In the original Solow-Swan model, the constant saving rate was an exogenous assumption of the model. In the Ramsey neoclassical growth model, this constant saving rate can be microfounded as the endogenous outcome of intertemporal consumption-savings decisions.

Figure 1: The Neoclassical Growth Model



Note: Determination of the steady-state capital-labor ratio in the closed-economy neoclassical growth model; $k = K/L$ denotes capital (K) per person (L); $y = Y/L$ corresponds to output (Y) per person (L); s is the constant saving rate; d represents the constant depreciation rate; and n is the constant exogenous rate of population growth.

capital is spread more thinly across the population), as again shown by the arrows on the horizontal axis. The steady-state capital-labor ratio (k^*) is where the increase in the capital stock per person from saving is exactly equal to the fall in the capital stock per person from population growth and depreciation at the intersection of the two solid lines.

3.2 Opening up the Neoclassical Growth Model

We next consider the implications of opening this closed economy to international trade in goods, maintaining the assumption of closed capital markets.[6] We assume that each economy has a single non-traded final good, which is produced using traded intermediate inputs from each country. Each country's intermediate input is produced using capital and labor according to a constant returns to scale Cobb-Douglas production technology. Intermediate inputs are horizontally differentiated between countries, such that the French good is differentiated from the German good, and so on for all of the other countries. Trade in these intermediate inputs is subject to "iceberg" transport costs, whereby a fraction of each unit of a country's good is absorbed in transport costs ("melts") when it is shipped between countries. If there is a constant elasticity of substitution between the differentiated goods produced by each country, static production and trade are the same as in the class of quantitative trade models with a constant trade elasticity discussed in the previ-

[6]See for example Baldwin and Forslid (1999), Anderson et al. (2015), Alvarez (2017), Brooks and Pujolas (2018), Mutreja et al. (2018), Ravikumar et al. (2019), and Baqaee and Malmberg (2025).

ous section.

The key difference is that each economy's capital stock is now endogenous and influenced by international trade. The opening of trade in goods reduces the consumption price index for the non-traded final good in each country through the conventional static gains from trade. Since the non-traded final good is also used for investment, this reduction in the consumption price index reduces the cost of investment, which raises the economy's steady-state capital stock. In this dynamic framework, we obtain sufficient statistics for the impact of opening the closed economy on steady-state welfare:

$$\frac{\mathbb{W}_n^{O*}}{\mathbb{W}_n^{A*}} = \left(\frac{1}{S_{nn}^{O*}}\right)^{\frac{1}{\mu\theta}}, \tag{2}$$

where we use an asterisk to denote a steady-state value and μ is the share of labor in production costs for each country's intermediate inputs.

Since both the domestic trade share and the labor share are less than one ($0 < S_{nn}^{O} < 1$ and $0 < \mu < 1$), the steady-state welfare gains from trade with capital accumulation in equation (2) are larger than the static welfare gains from trade in equation (1). The intuition is again that the opening of the closed economy to trade again operates like an improvement in production technology, because each country gains access to an improved technology for consumption. Instead of only having to consume its own good, it can consume the goods produced by many countries, which are all imperfect substitutes for one another. With an endogenous capital stock, this improvement in productivity induces capital accumulation, which magnifies the impact of this improvement in productivity on welfare.

In terms of Figure 1, the reduction in the cost of investment relative to the price of the final goods in each country shifts the sy curve upwards to sy' (in the same way that an improvement in domestic productivity would). This increase in savings raises the steady-state capital stock to k^{**} and leads to a period of capital accumulation and economic growth along the transition path to the new steady-state. Although the steady-state welfare gains from trade are magnified by capital accumulation, note that it takes time for these steady-state welfare gains to be realized, because capital accumulation occurs gradually along the transition path to steady-state. Since agents are typically assumed to discount the future, this discounting dampens the increase in the welfare gains from trade as a result of the induced capital accumulation.

While most open-economy research on on capital accumulation focuses on international trade in goods, there are also dynamic effects from opening capital markets, as shown in Kleinman et al. (2024). Suppose that each investor country can choose to invest wealth by holding capital in each host country and the capital holdings from different investor countries are imperfect substitutes. This assumption of imperfect substitutability in capital markets can be microfounded in a number of ways, including for example through idiosyncratic shocks to the productivity of capital holdings. Under these assumptions, the opening of capital markets operates like an improvement in the investment technology for each country. Instead of only having to accumulate capital using its own wealth holdings, each country can accumulate capital using the wealth holdings of many countries, which are imperfect substitutes for one another.[7]

In terms of Figure 1, the improvement in the investment technology from the opening of capital markets leads to a further outward shift in the sy curve. This increase in the efficiency of savings leads to a further rise in the steady-state capital stock and capital accumulation along the transition path to the new steady-state. More broadly, the distinction between wealth and capital under open capital markets emphasizes the distinction between gross domestic product (GDP) and gross national product (GNP). Whereas GDP captures the income paid to factors of production used in a country (regardless of their country of ownership), GNP captures the income received by factors of production owned by a country (regardless of the country in which they are used in production). Welfare depends on the income received by factors of production owned by a country. Therefore, under open capital markets, the welfare effects of globalization depend on wealth accumulation and GNP rather than on capital accumulation and GDP. Finally, when wealth is held as capital overseas, unanticipated shocks that change the relative prices of capital across countries give rise to unanticipated valuation effects.

3.3 Trade, Growth and Income Convergence

Capital accumulation can influence the impact of international trade in goods in other ways. Acemoglu and Ventura (2002) considers a setting with a final goods production technology that has constant (instead of diminishing) returns to capital (a so-called "AK-model"). Countries produce horizontally-differentiated goods under frictionless trade. Differences in the productivity of capital ("differences in A") lead to differences in the rate of capital accumulation across countries. In the closed economy, these differences in rates of capital accumulation lead to differences in rates of income growth and a divergence of the cross-country income distribution over time. In the open economy, a faster rate of capital accumulation in a given country leads to an increase in the relative supply of that country's good. Since countries' goods are imperfect substitutes, this increase in relative supply leads to a fall in the relative price of that country's good, in order to induce consumers worldwide to demand more of that country's good and satisfy the world goods market clearing condition. In contrast to the closed economy, this endogenous change in the terms of trade on world markets results in a stable world income distribution in the open economy, despite the different rates of capital accumulation across countries.

[7] These welfare gains from open capital markets are related to welfare gains from both foreign direct investment (FDI) and trade in goods in models of FDI (e.g., Ramondo and Rodríguez-Clare 2013 and Arkolakis et al. 2018). A key difference is that these models of FDI are static and abstract from capital accumulation.

While we have so focused on settings in which countries produce differentiated goods, Ventura (1997) embeds capital accumulation into a version of the Heckscher-Ohlin trade model, in which goods are homogeneous across countries. The world economy consists of two countries that differ in factor abundance (their initial relative supplies of capital and labor). There are two production sectors that differ in the factor intensity with which they use these two factors of production. Production technologies in each sector are assumed to be constant returns to scale in capital and labor, with diminishing marginal returns to capital alone.

In the closed economy, capital accumulation leads to a decline in the return to capital, because of diminishing marginal returns to capital. Therefore, economic growth gradually slows along the transition path to steady-state, with each country having a steady-state capital-labor ratio in each sector. In contrast, for a small open economy trading at constant world prices, the predictions are starkly different. As long the economy's factor supplies lie within the factor price equalization set, the return to capital is pinned down by world prices independently of the economy's own factor supplies (the famous factor price equalization or factor price insensitivity theorem). Therefore, a small open economy can continue to accumulate capital and enjoy rapid economic growth, without experiencing a fall in the return to capital. This theoretical prediction provides an explanation for apparent economic growth "miracles," in the form of the rapid growth of small open economies such as South Korea in the decades after the Second World War.

Although most research concerned with trade and capital accumulation has focused on physical capital, many of the same ideas could be applied to human capital. In the cross-country growth literature, taking account of human capital has been found to be important for both cross-country income convergence (e.g., Mankiw et al. 1992) and economic growth "miracles" (e.g., Young 1995). In the celebrated Stolper-Samuelson Theorem of the Heckscher-Ohlin model, trade liberalization has income distributional consequences for the relative wages of skilled and unskilled workers (e.g., Feenstra and Hanson 1999), which can affect incentives to acquire skills. Using data from Mexico during a period of major trade reforms, Atkin (2016) provides evidence that the growth of export manufacturing reduced years of schooling.

4 Learning by Doing

Although physical capital accumulation is one channel through which trade can have dynamic effects, empirical research finds that improvements in the productivity of factors of production (improvements in so-called "total factor productivity (TFP)") are an important source of long-run growth. This TFP growth is particularly prominent in advanced economies close to the technological frontier, such as the United States (e.g., Solow 1957). These empirical findings spurred the development of theoretical models of endogenous technological change, in which TFP growth is driven by endogenous improvements in production technology.

4.1 Learning by Doing and Endogenous Technological Change

One form of endogenous technological change that has a long lineage in economics is "learning by doing," which refers to the phenomenon whereby productivity improves with cumulative production of a good. Perhaps the most famous example of learning by doing comes from the production of "Liberty Ships" in the United States during the Second World War. For each individual shipyard, Searle (1945) plotted man hours per vessel against number of vessels completed to date in that yard, and found reductions in manhours per ship with each doubling of cumulative output from 12-24 percent. Estimating a production function that includes cumulative output as a separate explanatory variable, Rapping (1965) obtained a similar conclusion that a doubling of cumulative output led to a productivity improvement from 11-29 percent. More contemporary examples of industries where learning by doing is believed to be important include semiconductors, solar panels and electric vehicles (e.g., Irwin and Klenow 1994, Miller 2022).

The implications of learning by doing for the dynamic effects of trade depend crucially on the level at which learning by doing takes place: whether it is specific to a firm, an industry within a country, across industries within a country, within an industry across countries, or across countries and industries. Typically, learning by doing is assumed to extend beyond the boundaries of the firm through knowledge spillovers. Under this assumption, an individual firm does not fully internalize the benefits from learning by doing, because it takes into account the effect of its output on its own productivity, but not the effect on other firms' productivities. Empirical research finds that knowledge spillovers are larger within than between countries, because of the geographic localization of knowledge spillovers (e.g., Jaffe et al. 1993, Eaton and Kortum 1999).[8]

4.2 Learning by Doing and Comparative Advantage

In this case, where knowledge spillovers extend beyond the boundaries of the firm, but are specific to an industry and country, there is a two-way interaction between trade and learning by doing, with causality running in both directions. On the one hand, trade affects learning by doing, because it leads countries to specialize according to relative productivities across countries and industries (comparative advantage). Opening the closed economy to trade leads countries to produce more of (and export) the goods that they are relatively more efficient at making, and produce less of (and import) the goods that they are relatively less efficient at making. The resulting changes in specialization patterns affect cumulative output for each good and country and hence learning by

[8] In some ways, learning by doing is similar to static economies of scale that are external to the firm, as studied in Ethier (1982), Grossman and Rossi-Hansberg (2010), and Kucheryavyy et al. (2023). A key difference is that learning by doing occurs gradually over time.

doing and productivity growth. On the other hand, learning by doing feeds back to influence international trade. As countries produce more cumulative output in their industries of comparative advantage, this changes relative productivity across countries and industries, and hence changes patterns of specialization and trade.

This two-way interaction between trade and learning by doing provides microfoundations for "hysteresis" or "path dependence," according to which temporary shocks have permanent effects on patterns of specialization, growth and welfare, as highlighted in Krugman (1987). Suppose that a country does not have a comparative advantage in a good in an initial trade equilibrium, such that the good would produced in a foreign country in the absence of any policy intervention. Now suppose that a policy maker intervenes with an industrial policy, such as a production subsidy, which is sufficiently large to offset the absence of comparative advantage, and leads the good to be produced in home rather than in foreign. As home produces more cumulative output of that good, its productivity will rise through learning by doing. In contrast, since the foreign country no longer produces that good, its productivity will remain unchanged. Ultimately, with the passage of sufficient time, home's relative productivity for the good will rise to the point at which it has a comparative advantage in the good, and would produce the good even in the absence of any policy intervention. Therefore, the industrial policy can be removed, and a purely temporary policy has had a permanent effect on patterns of specialization and trade.

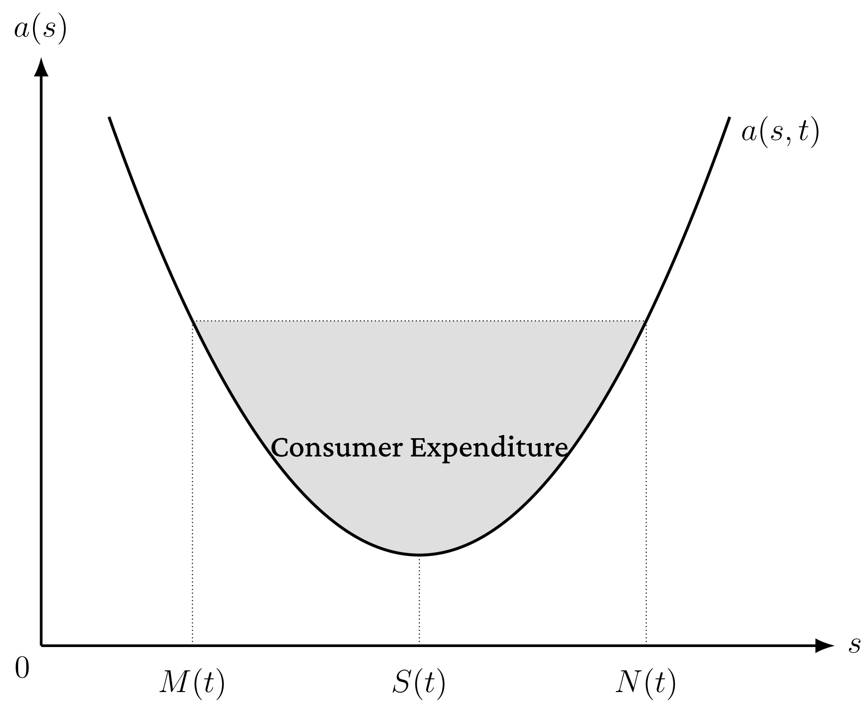
4.3 Trade, Learning by Doing and Growth

The presence of an externality from knowledge spillovers across firms implies that the market equilibrium is inefficient in models of learning by doing. Therefore, the removal of one distortion (such as a tariff or another barrier to trade) need not be welfare improving, because of the existence of another distortion in the economy (a classic insight from the "economics of second best"). As a result, it becomes possible for the opening of international trade to reduce welfare in some countries, as shown in Young (1991). Consider a world of two countries (D for "developed" and E for "emerging"), each of which has a single factor of production labor, and can produce any of a continuum of goods. Goods are horizontally differentiated from one another, such that consumer preferences exhibit a love of variety across goods. All goods are produced with a constant returns to scale production technology under conditions of perfect competition.

Goods differ in their level of technological sophistication s, with more sophisticated goods having lower potential labor requirements (higher potential productivity), but higher actual labor requirements when first introduced (lower actual productivity when first introduced). Labor requirements fall with cumulative production of a good through learning by doing. But this learning by doing is bounded, in the sense that there is a lower bound to the potential labor requirements for each good. For simplicity, we assume no international spillovers of knowledge, such that all learning by doing occurs within countries. Each country is characterized by a level of technological sophistication at a given point in time ($S(t)$), which corresponds to the most sophisticated good for which learning by doing has been exhausted. For all goods less sophisticated that this level ($s < S(t)$), learning by doing has been exhausted, and labor requirements are constant over time. For all goods more sophisticated than this level ($s > S(t)$), there is scope for further learning by doing, and labor requirements fall over time if the good is produced.

The closed-economy equilibrium is illustrated in Figure 2. Under perfect competition, the price of a good of sophistication s at time t equals its labor requirement ($a(s,t)$) times the wage ($w(t)$). The representative agent consumes the range of goods $s \in (M(t), N(t))$, where $M(t)$ is the least sophisticated good consumed at time t and $N(t)$ is the most sophisticated good consumed at time t. Actual unit labor requirements are assumed to be symmetric around $S(t)$, which implies that prices and the range of goods consumed are also symmetric around $S(t)$. The economy's autarkic growth rate depends on the rate of learning on those goods for which the potential for learning by doing has not yet been exhausted.

Figure 2: Closed Economy Equilibrium with Learning by Doing



Note: Closed economy equilibrium in Young (1991); $a(s,t)$ denotes the labor requirement for a good with technological sophistication s at time t; $S(t)$ is the level of technical sophistication of a country at time t; for all goods $s < S(t)$, labor requirements are constant, because learning by doing has been exhausted; for all goods $s > S(t)$ labor requirements fall over time when the good is produced, because there remains potential for learning by doing; $M(t)$ represents the least-sophisticated good that is produced at time t; $N(t)$ is the most sophisticated good that is produced at time t; gray shaded areas shows consumer expenditure in the closed economy equilibrium.

Now consider the opening of trade between these two countries, which are identical except for their labor supplies ($\bar{L}$) and level of technological sophistication ($S\left(t\right)$). We assume that $S^{D}\left(t\right) > S^{E}\left(t\right)$, which implies that relative labor requirements in the developed country ($a^{D}(s,t)/a^{E}(s,t)$) are lower in more-sophisticated goods, whereas those in the emerging country ($a^{E}(s,t)/a^{D}(s,t)$) are lower in less-sophisticated goods. As a result, specialization according to comparative advantage leads the developed country to reallocate resources towards more-sophisticated goods, where learning by doing can still occur. In contrast, the emerging country reallocates resources towards less-sophisticated goods, where the scope for learning by doing has been exhausted.

This specialization accordingly to comparative advantage affects rates of economic growth in the two countries. In the developed country, the reallocation of resources towards goods with more potential for learning by doing implies that the rate of output growth in the open economy is at least as great as that in the closed economy. In contrast, in the emerging country, the reallocation of resources towards goods with less potential for learning by doing implies that the rate of output growth in the open economy is less than or equal to that in the closed economy.

The evolution of the technological gap between the two countries ($X\left(t\right) \equiv S^{D}\left(t\right) - S^{E}\left(t\right)$) depends on the amount of labor allocated to the production of goods for which there remains potential for learning by doing, which depends not only of comparative advantage, but also on the relative population of the two countries. As a result, if the initial technological gap between the two countries is small enough, and the population of the emerging country is large enough relative to that of the developed country, the technological gap between the countries can fall over time. In this case, income per capita in the emerging country rises relative to that in the developed country, until eventually the roles of developed and emerging country are reversed.[9]

With the opening of trade, both countries experience conventional static welfare gains from trade, because of specialization according to comparative advantage. In the developed country, output growth is unchanged or higher in the open economy, which gives rise to dynamic welfare gains from trade. Therefore, the discounted flow of utility in the developed country is higher in the open economy. However, there is the caveat that if the emerging country is able to close the technological gap and become the developed country, then the country that initially starts out as developed can ultimately end up experiencing a reduction in its rate of output growth.

In comparison, the emerging country experiences a reduction in its rate of output growth, although not necessarily in its rate of consumption growth, because it enjoys a terms of trade gain from the developed country's productivity growth in more-sophisticated goods, where there remains the potential for learning by doing. Nonetheless, it is possible for the rate of consumption growth to fall in the emerging country, in which case it experiences dynamic welfare losses from trade.[10] In these circumstances, trade can either raise or reduce overall welfare in the emerg-

[9] Learning by doing and the associated reallocation across goods provides an explanation for the rapid structural transformation observed in East Asian miracle countries, such as South Korea, as emphasized in Lucas (1993).

[10] In a model in which countries differ in capability, goods differ in their complexity, and capability growth depends

ing country, depending on whether the conventional static welfare gains from trade are larger or smaller than these dynamic welfare losses from trade.

5 Endogenous Innovation and Growth

Although learning by doing is one form of endogenous technological change, these improvements in technology occur solely as a serendipitous by-product of production. In reality, firms devote considerable resources to intentional investments in innovation, including expenditure on research and development (R&D). These intentional investments are are motivated by expectations of future profits from successful innovation, as emphasized by Schmookler (1966).

5.1 Expanding Product Variety and Improving Product Quality

An early wave of research on "endogenous growth" developed models in which the economy's long-run rate of growth is endogenously determined by these intentional investments in innovation. In variety-based models, endogenous innovation takes the form of an expansion in product variety (as in Romer 1990 and Rivera-Batiz and Romer 1991). In quality-ladder models, it takes the form of increments in product quality or improvements in productivity (as in Aghion and Howitt 1992, Grossman and Helpman 1991b, and Kortum 1997).

Both approaches emphasize that ideas are different from conventional goods. Most of the other goods we consume are "rival," in the sense that one person consuming a cup of coffee prevents another person from imbibing the same draft. In contrast, ideas are "non-rival," in the sense that one person using Microsoft Windows does not prevent another person from using the same computer code. Nevertheless, ideas are "partially excludable," in the sense that Microsoft can exclude people from using Windows unless they purchase a license. The price for this license generates the profits that provide Microsoft the incentive to develop and improve Windows.

These distinctive features of ideas compared to other goods generate externalities and market failures. On the one hand, although Microsoft can prevent people using Windows without a software license, it cannot prevent people from reading the software code and understanding its principles, and then developing an improved alternative software package to Windows. This positive "knowledge spillover" provides a reason why the rate of innovation in the market equilibrium can be less than is socially optimal. On the other hand, when another company develops an alternative software package, it is concerned only with its own potential profits from that innovation, and does not take into account the destruction of Microsoft's monopoly profits from Windows. This negative spillover (the "business stealing" effect) provides a reason why the market rate of innovation

on a country's pattern of specialization, Atkin et al. (2025) provides quantitative evidence of dynamic welfare losses from trade that are pervasive, albeit small for the median country.

can be greater than is socially optimal. In quality-ladder models, technologies are vertically differentiated, such that each innovation displaces the existing state-of-the-art technology. Growth becomes a process of "creative destruction," as emphasized in Schumpeter (1942), and hence these frameworks are often referred to as Schumpeterian models.[11]

These externalities and market failures imply that the rate of growth in the market equilibrium can differ from the socially-optimal rate of growth that would be chosen by a planner. Therefore, the reallocations of resources induced by international trade can have first-order effects on welfare, by either exacerbating or mitigating existing market failures. For this reason, the dynamic welfare effects of trade in models of endogenous innovation often can be large relative to its static welfare effects in conventional trade models where the market equilibrium is efficient.

5.2 Trade and Endogenous Innovation

Both variety-based and quality-ladder models of endogenous innovation highlight a number of channels for dynamic effects of trade. First, international trade increases product market competition, because domestic firms are exposed to foreign competitors. In conventional Schumpeterian models, this greater product market competition reduces the monopoly profits from innovation, which lowers incentives to invest in innovation. This pro-competitive effect highlights the traditional trade-off between the static and dynamic effects of monopoly. While monopoly power reduces current welfare by raising prices relative to marginal costs, it can raise future welfare by providing the incentives for innovation.

Existing empirical evidence suggests that greater product market competition can raise rather than reduce the incentives for innovation, as in Nickell (1996) and Aghion et al. (2005).[12] Extended Schumpeterian models highlight a number of channels through which these positive effects of product market competition can occur. In models of "neck and neck" competition between firms, greater competition can increase incentives to innovate to "escape competition," as in Aghion et al. (2001). In settings where successive vintages of technologies coexist and are gradually improved through subsequent development, greater competition can speed up innovation by reallocating resources towards the latest vintages, as in Aghion and Howitt (1996). In the presence of principal-agent problems within firms, greater competition can enhance innovation by tightening incentive compatibility constraints, as in Aghion et al. (1999).

Second, models of endogenous innovation often feature scale effects, because upfront investments in innovation correspond to a fixed cost, whereas the monopoly profits from successful innovation increase with market size. Therefore, international trade can enhance incentives to innovate

[11] See Aghion and Howitt (1997), Aghion et al. (2014) and Aghion (2026).

[12] Existing evidence for the China trade shock yields ambiguous conclusions about its impact on innovation. While Bloom et al. (2016) finds a positive effect, Autor et al. (2020) finds a negative effect.

by raising the profits from successful innovation as a result of greater market size. Whether these market size effects are realized depends on market structure, and the extent to which the greater profits from an expansion in market size are dissipated through the entry of firms. In models of expanding product variety with monopolistic competition and constant elasticity of substitution (CES) preferences, the expansion in market size as a result of international trade is entirely accommodated through firm entry, leaving incentives for innovation unchanged, as in Grossman and Helpman (1991a) and Rivera-Batiz and Romer (1991).

Third, the opening of a closed economy allows for international knowledge spillovers. In both product variety and product quality models of innovation, each generation of researchers builds on the existing stock knowledge, or "stands on the shoulders of giants" in the memorable phrase of Isaac Newton. In the open economy, researchers in each country can build on a larger stock of ideas than in the closed economy, which raises the productivity of research, and thereby raises the long-run growth rate in Grossman and Helpman (1991a) and Rivera-Batiz and Romer (1991). These effects of international knowledge spillovers relative to international trade in goods depend crucially on the research technology: whether the research sector is "knowledge-based" (using only researchers and ideas) or takes a "lab-equipment" form (using existing goods as inputs into research), as explored in Rivera-Batiz and Romer (1991). International trade in goods also can eliminate duplication in research, by ensuring that countries specialize in distinct varieties of goods, or can act as a conduit for international knowledge spillovers, as in the classic example of the reverse engineering of products (e.g., Coe and Helpman 1995).

Fourth, the opening of international trade leads to specialization across sectors according to patterns of comparative advantage. To the extent that sectors differ in rates of innovation, this specialization affects aggregate output growth through a change in sectoral composition, as in Grossman and Helpman (1991a). Echoing findings for learning by doing above, countries that specialize in sectors with low rates of innovation can experience a decline in output growth in the open economy relative to the closed economy. Even if output growth falls, these countries need not experience a decline in consumption growth, because of the improvement in their terms of trade from innovation in their trade partners. In the absence of international knowledge spillovers, comparative-advantage-based models of endogenous innovation can exhibit hysteresis and path dependence, because temporary shocks can affect the accumulation of national knowledge stocks, and hence have permanent effects on patterns of specialization and trade.

5.3 Endogenous Versus Semi-Endogenous Growth

Early "knowledge-based" models of endogenous innovation assumed an elasticity of the productivity of research workers with respect to the existing stock of knowledge of one, with the result that the change in knowledge is proportional to the existing stock of knowledge. This specification gives rise to endogenous long-run growth. Therefore, policies that raise employment in the research sector permanently raise the economy's long-run growth rate. In contrast to this theoretical prediction, recent decades have witnessed an increased share of resources devoted to the research sector without a corresponding increase in the economy's rate of long-run growth, as shown in Jones (1995b) and Bloom et al. (2020). A classic example is Moore's Law, where the number of researchers required today to achieve a doubling of computer chip density is more than 18 times larger than the number required in the early 1970s. To rationalize this empirical evidence, Jones (1995a) develops a semi-endogenous growth model, in which the elasticity of the productivity of research workers with respect to the existing stock of knowledge is less than one. In this semi-endogenous specification, policies that change the share of resources devoted to the research sector affect economic growth along the transition path to steady-state and the steady-state level of income per capita. But these policies have no effect on the economy's long-run growth rate of income, which is instead determined by exogenous population growth.

6 Producer Heterogeneity and Technology Diffusion

The research on endogenous technological change in the previous two sections assumed a representative firm within a given sector and country. More recent research has examined the dynamic effects of trade in models of heterogeneous firms with endogenous distributions of productivity across firms.[13] In these frameworks, trade liberalization changes the sets of firms producing in each country and serving each market, which in turn affects firms' incentives to adopt new technologies and the diffusion of technologies across firms.

6.1 The Canonical Model of Firm Heterogeneity

The canonical framework for modelling firm heterogeneity is the Melitz (2003) model of heterogeneous firms in differentiated product markets. In this framework, a competitive fringe of potential firms can enter an industry by paying an upfront fixed entry cost, which is thereafter sunk. Potential entrants face uncertainty about their productivity in the industry. Once the sunk entry cost is paid, a firm draws its productivity from a fixed distribution. In this formulation, the fixed entry cost can be viewed as an investment in R&D, and the productivity draw can be interpreted as an innovation. In this canonical model, firm productivity is assumed to remain fixed after entry, but firms face a constant exogenous probability of death as a result of *force majeure* events.

Firms produce horizontally-differentiated varieties within the industry under conditions of monopolistic competition. Firms must incur a fixed cost in order to produce and profits are increas-

[13] For a review of the wider literature on firm heterogeneity and international trade, see Bernard et al. (2007) and Melitz and Redding (2014).

ing in firm productivity. Therefore, firms drawing a productivity level below some lower threshold (the "zero-profit productivity cutoff") would make negative profits if they chose to produce, and hence exit the industry. Firms face additional fixed and variable costs of exporting. Therefore, of the active firms within the industry, only those who draw a productivity above a higher threshold (the "export productivity cutoff") find it profitable to export in equilibrium.

Trade liberalization increases profits that existing exporters can earn in foreign markets, and reduces the export productivity cutoff above which firms export, thereby inducing entry into exporting. In contrast, the profitability of low-productivity firms that only serve the domestic market declines, because of increased product market competition from high-productivity foreign firms, and increased labor-market competition with high-productivity domestic firms. This reduction in domestic market profits induces some low productivity firms who were previously marginal to exit the industry. As low-productivity firms exit, and as output and employment are reallocated towards higher-productivity firms, average industry productivity rises.[14]

6.2 Firm Heterogeneity and Endogenous Growth

In Melitz (2003), a firm's productivity remains fixed after it is drawn upon entry. In reality, firms make investments in innovation, which lead to endogenous changes in firm productivity over time, as in Atkeson and Burstein (2010). In this case, trade liberalization affects welfare through a rich range of mechanisms, including firm exit, exporting and process innovation. Despite these multiple mechanisms, the aggregate effect of trade liberalization on welfare is disciplined by the free entry condition that equates the expected value of firm entry to the sunk entry cost. Other things equal, a reduction in barriers to international trade raises the profits associated with firm entry. In equilibrium, in order to satisfy the free-entry condition, this increase in expected profits must be offset by an increase in the real wage and a change in aggregate output, both of which are determined by aggregate productivity. To a first-order approximation, the required change in aggregate productivity is independent of the details of whether it is achieved through firm entry, exporting or process innovation. A key implication of this insight is that expanding the range of mechanisms through which firms can respond to trade liberalization does not necessarily affect the overall magnitude of the aggregate welfare gains from trade.

Whether incorporating additional mechanisms affects the overall size of the aggregate welfare gains from trade depends on the extent to which the market equilibrium is efficient. If there are knowledge spillovers across firms, the market equilibrium is inefficient, because firms do not internalize these knowledge spillovers. Suppose for example that entering firms learn from incumbents, as analyzed in Sampson (2016). Since only firms with a sufficiently high productivity

[14] In dynamic models, the exit of low-productivity firms and the entry into exporting by high-productivity firms occur gradually over time, as analyzed in Alessandria et al. (2021b) and reviewed in Alessandria et al. (2021a).

draw find it profitable to enter, the incumbent distribution is a truncation of the entry distribution, which implies that each generation of entering firms learns from an incumbent distribution that is shifting progressively to the right, thereby resulting in endogenous long-run growth.

When the economy is opened up to trade, the additional profits from export opportunities must be offset by a lower probability of successful entry, in order for expected profits to remain equal to the unchanged sunk entry cost. Therefore, the productivity cutoff below which firms exit shifts upwards, which raises the average productivity of incumbent firms. This increased selection of more productive firms raises the rate of learning, and accelerates the pace of endogenous growth, thereby providing a new source of dynamic gains from trade. For calibrated values of the model's parameters, this new source of dynamic gains approximately triples the overall welfare gains from trade relative to a static heterogenous firm model without innovation.

Instead of assuming that entrants learn from incumbents, Perla et al. (2021) allow the distribution of productivity across incumbents to evolve endogenously over time. Each incumbent firm experiences stochastic productivity shocks and chooses whether to incur a fixed cost to adopt new technologies already in use by other firms in their home country. Opening to trade increases the spread of profits between the most and least productive firms, because of a combination of increased export opportunities and foreign competition. This increased dispersion in profits raises the incentive to upgrade technology and hence accelerates the pace of endogenous growth. The decentralized market equilibrium features a rate of technology adoption that is too slow relative to the social optimum. Therefore, international trade by accelerating the rate of technology adoption leads to large welfare gains through reduced inefficiency.

6.3 Firm Heterogeneity and Creative Destruction

In Melitz (2003) and the variety-based models of growth in Section 5, innovation takes the form of the creation of new varieties. In contrast, in the quality-ladder model of growth in Section 5, the incumbent supplier of the state-of-art technology is entirely displaced by innovation from a new entrant. Therefore, these two different approaches to endogenous innovation offer starkly different perspectives on the extent to which growth involves creative destruction. In between these two extremes, innovation can encompass the creation of new varieties by either entrants or incumbents, improvements in quality or productivity for existing varieties within incumbent firms, or creative destruction when a firm improves on and takes over a variety supplied by another firm, as analyzed in Klette and Kortum (2004) and Garcia-Macia et al. (2019).

Using micro data on firms in the United States, Garcia-Macia et al. (2019) provides empirical evidence on the relative importance of these different forms of innovation. Most growth originates from incumbents rather than from new entrants, because most entering firms are small. Most growth also occurs through quality or productivity improvements within existing varieties rather than from an expansion in the number of varieties. Creative destruction contributes to around 25 percent of growth, with the remainder mostly accounted for by quality or productivity improvements for existing varieties within incumbent firms.

When creative destruction involves innovators in one country taking over the market for an existing product in another country, it leads to changes in patterns of trade in goods, as analyzed in Hsieh et al. (2023). In principle, innovators in each country could build either on the technology of the products sold in their market or on the blueprints of local firms. When innovators can build on the technology of sellers (including imports), international trade has dynamic effects on welfare by facilitating the international flow of ideas. Even taking into account the gradual convergence to steady-state along the transition path, these dynamic gains from trade through the diffusion of ideas are found to be large relative to the static gains from trade, and equivalent to a 31 percent increase in consumption in the United States.

6.4 Global Diffusion of Ideas

Other related research has sought to deepen our understanding of the dynamic effects of international trade by modelling the microeconomic process through which ideas diffuse between individual producers, as in Buera and Oberfield (2020).

Idea diffusion is modelled as a process that involves random interaction among producers of different goods or countries. New ideas arrive to potential producers of a good randomly. Each idea corresponds to a technology to produce a particular good with a specific productivity. These new ideas build on insights from others, but there is randomness in the adaptation of these insights. Therefore, the productivity of each idea has a random original component, which is combined with an random insight drawn from the distribution of ideas across other producers. This specification captures the notion that interactions with more productive individuals typically lead to more useful insights, but allows for randomness in the adaptation of knowledge from elsewhere to one's own specific context. The arrival of these new ideas leads to a gradual outward shift in the productivity distribution and endogenous long-run growth.

Opening the closed economy to trade in goods affects the quality of the insights drawn by producers, because it determines the set of technologies used in each country and the set of goods sold in each market. When insights are drawn from sellers in each market, the overall welfare gains from trade are up to three times larger than the static gains from trade, because of these dynamic effects through idea diffusion. For the preferred calibration of the model, the overall welfare gains from trade and the fraction of productivity growth explained by trade in goods are more than twice as large as in a special case of the model without idea diffusion. The calibrated model is able to explain a substantial fraction of the rapid productivity growth observed in the "growth miracles" of China, South Korea, and Taiwan through the mechanism of idea diffusion.

6.5 Quantifying Dynamic Gains

Although many of these studies suggest potentially large dynamic welfare gains from trade, there is much less consensus about how to discipline the magnitude of these dynamic welfare gains using a small number of sufficient statistics than for the conventional static welfare gains from trade. In Section 2, we saw there is a tight mapping in static trade models from the sufficient statistics of the domestic trade share and the trade elasticity to the quantitative magnitude of the welfare gains from trade. In contrast, in dynamic models, the mapping from the observed data to the quantitative magnitude of the welfare gains from trade is considerably more subtle, often depending on the model's full general equilibrium structure.

One promising approach uses techniques from network theory and data on patent citations to quantify the innovation network in Liu and Ma (2026). Innovation is assumed to occur through intentional investments in R&D. Future innovations benefit from past innovations through a network of knowledge spillovers that are measured using patent citations. Given data on R&D investments and patent citations, the observed allocation of R&D across countries and sectors can be compared to the socially-optimal allocation that would be chosen by a planner. Observed R&D allocations are found to diverge substantially from socially-optimal allocations. Increasing the efficiency of the allocation of R&D resources in the United States to the levels of Japan would increase consumption-equivalent welfare by around 8 percent, comparable to the upper bound for the conventional static welfare gains in trade for the United States in Section 2.

Another promising approach uses the distinction in dynamic trade models between the short-run trade elasticity (the response of trade flows to trade costs holding factor supplies and production technologies constant) and the long-run trade elasticity (the response of trade flows after allowing factor supplies and production technologies to respond to changes in trade costs).[15] In a class of dynamic trade models in which the number of firms or the number of consumers served by firms evolve gradually over time, Boehm et al. (2025) shows that the welfare gains from trade can be summarized by the domestic trade share and the long-run elasticity of trade with respect to trade costs. This long-run trade elasticity can be recovered from the estimated responses of trade flows to tariff changes in both the short and long-run. Implementing this approach, the dynamic gains from trade are found to be large relative to their static counterparts. Since convergence to steady-state is relatively rapid, accounting for the transition path has only a modest impact on the magnitude of the welfare gains from trade relative to steady-state comparisons.

Developing dynamic trade models of learning by doing and endogenous innovation that feature similar tight relationships between the observed data and the quantitative magnitude of the welfare gains from trade remains an active area of ongoing research.

[15] For empirical evidence that trade elasticities are smaller in absolute value in the short-run than in the long-run, see for example Ruhl (2008), Anderson and Yotov (2020), and Boehm et al. (2023).

7 Implications for Trade and Industrial Policy

The externalities and market failures in dynamic trade models provide a potential rationale for activist trade and industrial policies. Recent years have seen a resurgence of interest in such policy interventions, including for example the bi-partisan CHIPS and Science Act in the United States. This resurgence of interest reflects a combination of considerations. First, the transportation disruptions during and after the COVID-19 pandemic raised concerns about the resilience of global value chains (GVCs), in which stages of production span national borders. Second, growing geopolitical tensions between the U.S. and China and the Russia-Ukraine war have heightened national security concerns about sourcing critical intermediate inputs or raw materials from abroad. Third, policy makers have sought to promote domestic manufacturing activity, often with the stated aim of creating well-paid jobs for middle-class workers.[16]

7.1 Industrial Policy and Infant Industries

One argument sometimes proposed for these activist trade and industrial policies is that temporary protection is needed while an industry is in its infancy to cover initial losses, until learning by doing or other technological innovations enable the industry to become profitable in its maturity, at which point the protection can be removed. This idea has a long history in economics dating back at least to Mill (1848) and is referred to as the "infant industry" argument. This idea is also related to the properties of hysteresis and path dependent in Krugman (1987) in Section 4. Prominent examples of countries in which industrial policies were successful in promoting the targeted industries include some East Asian newly-industrializing countries (NICs), such as Japan, South Korea and China. However, other NICs followed more market-based strategies, such as Hong Kong. Furthermore, there are other prominent examples of apparently unsuccessful industrial policies in countries in Latin America, such as Argentina.[17]

Despite the resurgence of interest in activist trade and industrial policies, the empirical evidence in support of their success is scarce relative to this level of interest. Evidence that temporary protection can enable an industry to subsequently become economically viable is provided by Juhász (2018) using the natural experiment of the Napoleonic blockade as an exogenous source of variation. Regions in the French Empire which became better protected from trade with the British for exogenous reasons during the Napoleonic Wars (1803–1815) increased capacity in mechanized cotton spinning by more than regions which remained more exposed to trade. Even after the end of the war, these better-protected regions had higher activity in mechanized cotton spinning, at least until the second half of the nineteenth century.

[16] For a discussion of this resurgence of interest in industrial policy, see Juhász et al. (2024).

[17] For evidence from South Korea, see Amsden (1989), Choi et al. (2024), and Lane (2025). For evidence from China, see Kalouptsidi (2018) and Liu (2019). For evidence from Latin America, see Little et al. (1970).

However, the finding that temporary protection can enable an industry to subsequently become economically viable is not sufficient to establish that this policy is welfare improving. Another more demanding requirement is that the net present value of the stream of initial losses and future profits is greater than or equal to zero. But this additional requirement by itself is still not sufficient. In the absence of any market failure, if the net present value of profits in the industry is non-negative, firms should be willing to borrow on private capital markets to cover the initial losses, and pay back the amount borrowed from future profits. If firms are unwilling to borrow to finance these initial losses because of credit market imperfections, then policy interventions instead should be targeted to alleviate these credit market imperfections, in order to avoid introducing distortions elsewhere in the economy. Additionally, even if the net present value of profits is positive, this is not enough to ensure that activist trade and industrial policies are welfare improving, because consumer surplus also needs to be taken into account.

Ultimately, the case for activist trade and industrial policies rests on some form of market failure, which introduces inefficiencies into the decentralized decisions of private-sector agents. In this case, the design of these policies should be targeted at the source of the market failure in order to avoid introducing additional inefficiencies. For example, if knowledge spillovers from learning by doing within an industry are the source of the market failure, a production subsidy dominates a tariff, because a production subsidy only distorts producer decisions, whereas the tariff distorts both producer and consumer decisions.

7.2 Strategic Trade and Industrial Policy

These arguments for policy intervention connect with an earlier literature on strategic trade policy, which emphasized imperfect competition as the source of market failure.[18] If there are super normal profits within an industry, there can be case for activist trade and industrial policies to shift profits from foreign to domestic firms. One of the limitations of this earlier strategic trade policy literature is that the policy prescriptions can be highly sensitive to the details of the strategic interaction between firms. For example, if firms compete in foreign export markets in quantities under Cournot competition, an export subsidy can shift profits from foreign to domestic firms. In contrast, if firms compete in foreign export markets in prices under Bertrand competition, an export tax is the appropriate policy to shift profits from foreign to domestic firms.

Knowing the details of strategic interaction between firms within industries imposes strong informational requirements on policy makers. Additionally, arguments for policy intervention based on imperfect competition typically focused on a single industry in partial equilibrium, and often require substantial qualification in general equilibrium. For example, if several industries employ the same factor of production that is in limited supply for the economy as a whole, protection of one

[18] For overviews, see Krugman (1994) and Brander (1995).

industry based on strategic considerations acts as anti-protection for other industries using that same factor of production, because they face increased competition for that factor of production. Finally, the impact of one country introducing an industrial policy can be offset by the introduction of retaliatory industrial policies by its trade partners.

7.3 Industrial Policy and Endogenous Technological Change

In contrast, arguments for policy intervention in dynamic trade models are typically based on externalities, such as knowledge spillovers from learning by doing and innovation. These arguments often take into account reallocations across industries in general equilibrium. In the presence of externalities such as knowledge spillovers, private-sector agents decisions about which goods to produce today may may not reflect the potential for productivity growth in the future. As a result, international trade can induce a country to specialize in goods that lower its rate of economic growth, and policy interventions that induce alternative patterns of specialization can raise its rate of economic growth, as discussed for the Young (1991) model in Section 4. Perhaps surprisingly, such policy interventions can even raise the welfare of all countries in the world, as shown in Redding (1999). Such a possibility arises when the failure to internalize the potential for productivity growth in the future leads countries to specialize in a set of goods that collectively lowers the rate of growth of consumption in all countries.

When industries are connected by an input-output network, arguments for activist trade and industrial policies become considerable more complicated, because market imperfections in one industry propagate to other industries through the production network. Liu (2019) provides an analytical characterization of industrial policy when economic sectors form a production network. Starting from a decentralized, no-intervention economy, policies can be guided by a measure of "distortion centrality" that integrates all distortionary effects of market imperfections through the production network. In hierarchical production networks, in which sectors follow a pecking order so that upstream sectors supply a disproportionate fraction of output to other relatively upstream sectors, distortion centrality reduces to a measure of the upstreamness of the sector. Therefore, the analysis provides a microfoundation for policy interventions targeting upstream sectors, as observed empirically in China and South Korea.

Evidence on the quantitative magnitude of the welfare gains from activist trade and industrial policies is provided by Bartelme et al. (2025), using a multi-sector quantitative trade model with static external economies of scale within sectors and countries. The empirical strategy to estimate the strength of external economies of scale uses two ideas. First, if there are positive external economies of scale, larger sectors should tend to sell their products at lower prices. Second, if prices are lower in those sectors, quantities demanded should tend to be higher. These two insights imply that one can estimate scale elasticities by tracing out the impact of exogenous (i.e., demand driven) variation in the size of sectors on equilibrium quantities. This structural estimation finds sizable external economies of scale that differ across manufacturing sectors.

Despite these sizable external economies of scale, the welfare gains from the optimal industrial policy are found to be relatively modest. This pattern of results reflects the relatively low elasticities of substitution across sectors and relatively high trade costs between countries. Together these two forces imply relatively little reallocation across sectors in response to the optimal industrial policy. These empirical findings highlight that in order to obtain large welfare gains from activist trade and industrial policies one requires a combination of large externalities, the ability for policy markers to overcome the informational requirements of estimating these externalities, and substantial reallocation in response to policies internalizing those externalities.

8 Conclusions

The existence of aggregate welfare gains from trade is one of the classic insights from the field of international economics. Opening a closed economy to trade acts like an improvement in production technology, because it provides an alternative method for obtaining goods to consume. Instead of having to produce everything itself, an economy can specialize in some goods and trade at world market prices in order to obtain other goods. These conventional aggregate welfare gains from trade are static, in the sense that they take an economy's factor supplies and production technology as given at a point in time. In the last two decades, a great deal of consensus has been achieved about the quantitative magnitude of these static welfare gains from trade, with a central figure for the United States of around 5 percent of real GDP.

However, another line of research in the growth literature suggests that by taking factor supplies and production technology at a point in time as given, these conventional static welfare gains abstract from dynamic effects of international trade through factor accumulation and endogenous technological change over time. These dynamic effects have a number of broad implications for the welfare gains from trade. First, physical capital accumulation can magnify the impact of trade on steady-state welfare in dynamic models relative to the conventional welfare gains from trade in static models. However, the accumulation of additional physical capital must be paid for by lower consumption along the transition path towards steady-state. Furthermore, this factor accumulation occurs gradually over time, with the result that the higher steady-state levels of welfare must be discounted for the time taken to converge to steady-state. Second, models of endogenous technological innovation typically feature externalities and market failures. Therefore, the reallocations of resources induced by international trade can have first-order effects on welfare, by either exacerbating or mitigating existing market failures. This insight explains why the dynamic welfare effects of trade can be large relative to its static welfare effects in conventional trade models where the market equilibrium is efficient.

Recognizing dynamic effects of trade through factor accumulation and endogenous technological change also leads to a number of more specific economic insights. Capital accumulation is influenced by changes in the terms of trade on international markets, which can help to explain apparent economic growth miracles, and can also rationalize a stable world income distribution despite persistent differences in rates of capital accumulation across countries. Static gains from trade that lower the consumption price index also reduce the cost of investment, which stimulates capital accumulation. When wealth is held as capital overseas, the welfare effects of trade depend on its impact on GNP rather than its impact on GDP, and anticipated shock can have valuation effects by changing the relative price of capital holdings across countries. Temporary shocks to patterns of international specialization at a point in time, by changing rates of endogenous innovation can can have permanent effects patterns of specialization and trade, output growth and welfare. In the presence of market failures, protectionist trade and industrial policies can potentially be welfare improving. But such policies should be closely targeted at the source of the market imperfection, impose strong information requirements on a policy maker, and any gains from domestic policies can be offset by foreign retaliation.

Despite the considerable progress in delineating mechanisms for dynamic welfare effects of trade, there remains much less agreement about their quantitative magnitude than for the conventional static gains from trade. In the coming years, we anticipate substantial further progress in disciplining the magnitude of these dynamic welfare effects using data, in order to place them on a similar quantitative footing as their static counterparts.

References

Acemoglu, D. and J. Ventura (2002): "The World Income Distribution," *Quarterly Journal of Economics*, 117, 659–694.

Adão, R., C. Arkolakis, and S. Ganapati (2026): "From Heterogeneous Firms to Heterogeneous Trade Elasticities: The Aggregate Implications of Firm Export Decisions," *NBER Working Paper*, 28081.

Aghion, P. (2026): "Nobel Lecture: The Economics of Creative Destruction," *American Economic Association: Papers and Proceedings*, 116, 2324–2356.

Aghion, P., U. Akcigit, and P. Howitt (2014): "What Do We Learn From Schumpeterian Growth Theory?" in *Handbook of International Economics*, ed. by P. Aghion and S. N. Durlauf, Amsterdam: Elsevier North-Holland, vol. 2, chap. 1, 515–563.

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

Aghion, P., M. Dewatripont, and P. Rey (1999): "Competition, Financial Discipline and Growth," *Review of Economic Studies*, 66, 825–852.

Aghion, P., C. Harris, P. Howitt, and J. Vickers (2001): "Competition, Imitation and Growth with Step-by-Step Innovation," *Review of Economic Studies*, 68, 467–492.

Aghion, P. and P. Howitt (1992): "A Model of Growth Through Creative Destruction," *Econometrica*, 60, 323–351.

——— (1996): "Research and Development in the Growth Process," *Journal of Economic Growth*, 1, 49–73.

——— (1997): *Endogenous Growth Theory*, Cambridge MA: MIT Press.

Alessandria, G., C. Arkolakis, and K. J. Ruhl (2021a): "Firm Dynamics and Trade," *Annual Review of Economics*, 13, 253–80.

Alessandria, G., H. Choi, and K. J. Ruhl (2021b): "Trade Adjustment Dynamics and the Welfare Gains from Trade," *Journal of International Economics*, 131, 103458.

Alvarez, F. (2017): "Capital Accumulation and International Trade," *Journal of Monetary Economics*, 91, 1–18.

Amsden, A. (1989): *Asia's Next Giant: South Korea and Late Industrialization*, Oxford: Oxford University Press.

Anderson, J. E., M. Larch, and Y. V. Yotov (2015): "Growth and Trade with Frictions: A Structural Estimation Framework," NBER Working Paper No. 21377.

Anderson, J. E. and Y. V. Yotov (2020): "Short-run Gravity," *Journal of International Economics*, 103341.

Arkolakis, C., A. Costinot, and A. Rodriguez-Clare (2012): "New Trade Models, Same Old Gains," *American Economic Review*, 102, 94–130.

Arkolakis, C., N. Ramondo, A. Rodríguez-Clare, and S. Yeaple (2018): "Innovation and Production in the Global Economy," *American Economic Review*, 108, 2128–73.

Atkeson, A. and A. T. Burstein (2010): "Innovation, Firm Dynamics, and International Trade," *Journal of Political Economy*, 118, 433–484.

Atkin, D. (2016): "Endogenous Skill Acquisition and Export Manufacturing in Mexico," *American Economic Review*, 106, 2046–85.

Atkin, D., A. Costinot, and M. Fukui (2025): "Globalization and the Ladder of Development: Pushed to the Top or Held at the Bottom?" *Review of Economic Studies*, forthcoming.

Autor, D., D. Dorn, G. H. Hanson, G. Pisano, and P. Shu (2020): "Foreign Competition and Domestic Innovation: Evidence from US Patents," *American Economic Review: Insights*, 3, 357–74.

Baldwin, R. and R. Forslid (1999): "Incremental Trade Policy and Endogenous Growth: A q-theory Approach," *Journal of Economic Dynamics and Control*, 23, 797–822.

Baqaee, D. and H. Malmberg (2025): "Long-Run Effects of Trade Wars," *NBER Working Paper*, 33702.

Bartelme, D., A. Costinot, D. Donaldson, and A. Rodríguez-Clare (2025): "The Textbook Case for Industrial Policy: Theory Meets Data," *Journal of Political Economy*, 133, 1527–1573.

Barwick, P. J., M. Kalouptsidi, and N. B. Zahur (2025): "Industrial Policy Implementation: Empirical Evidence from China's Shipbuilding Industry," *Review of Economic Studies*, 92, 3611–3648.

Bernard, A. B., J. B. Jensen, S. J. Redding, and P. K. Schott (2007): "Firms in International Trade," *Journal of Economic Perspectives*, 21, 105–130.

Bernhofen, D. M. and J. C. Brown (2005): "An Empirical Assessment of the Comparative Advantage Gains from Trade: Evidence from Japan," *American Economic Review*, 95, 208–225.

Bloom, N., M. Draca, and J. Van Reenen (2016): "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," *Review of Economic Studies*, 83, 87–117.

Bloom, N., C. I. Jones, J. Van Reenen, and M. Webb (2020): "Are Ideas Getting Harder to Find?" *American Economic Review*, 110, 1104–1144.

Boehm, C. E., A. Levchenko, and N. Pandalai-Nayer (2023): "The Long and Short (Run) of Trade Elasticities," *American Economic Review*, 113, 861–905.

Boehm, C. E., A. Levchenko, N. Pandalai-Nayer, and H. Toma (2025): "Dynamic Models: New Gains from Trade?" *NBER Working Paper*, 19148.

Brander, J. A. (1995): "Strategic Trade Policy," in *Handbook of International Economics*, ed. by G. M. Grossman and K. Rogoff, Amsterdam: Elsevier North-Holland, chap. 27, 1395–1455.

Brooks, W. J. and P. S. Pujolas (2018): “Capital Accumulation and the Welfare Gains from Trade,” *Economic Theory*, 66, 491–523.

Buera, F. J. and E. Oberfield (2020): “The Global Diffusion of Ideas,” *Econometrica*, 88, 83–114.

Caliendo, L. and F. Parro (2015): “Estimates of the Trade and Welfare Effects of NAFTA,” *Review of Economic Studies*, 82, 1–44.

——— (2022): “Trade Policy,” in *Handbook of International Economics*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, London: Elsevier North-Holland, 219–295.

Choi, J., A. Levchenko, D. Ruzic, and Y. Shim (2024): “Superstars or Supervillains? Large Firms in the South Korean Growth Miracle,” *NBER Working Paper*, 32648.

Coe, D. and E. Helpman (1995): “International R&D Spillovers,” *European Economic Review*, 39, 859–887.

Costinot, A. and A. Rodríguez-Clare (2014): “Trade Theory with Numbers: Quantifying the Consequences of Globalization,” in *Handbook of International Economics*, ed. by E. Helpman, K. Rogoff, and G. Gopinath, Amsterdam: Elsevier, vol. 4, chap. 4, 197–262.

——— (2018): “The US Gains from Trade: Valuation Using the Demand for Foreign Factor Services,” *Journal of Economic Perspectives*, 32, 3–24.

Costinot, A. and I. Werning (2023): “Robots, Trade, and Luddism: A Sufficient Statistic Approach to Optimal Technology Regulation,” *Review of Economic Studies*, 90, 2261–2291.

——— (2026): “Should we Tax Trade? A Pigouvian Perspective,” *Journal of Economic Perspectives*, forthcoming.

Dhingra, S., H. Huang, G. Ottaviano, J. P. Pessoa, T. Sampson, and J. Van Reenen (2017): “The Costs and Benefits of Leaving the EU: Trade Effects,” *Economic Policy*, 32, 651–705.

Eaton, J. and S. Kortum (1999): “International Technology Diffusion: Theory and Measurement,” *International Economic Review*, 40, 537–570.

Ethier, W. J. (1982): “Decreasing Costs in International Trade and Frank Graham’s Argument for Protection,” *Econometrica*, 50, 1243–1268.

Feenstra, R. C. and G. H. Hanson (1999): “The Impact of Outsourcing and High-Technology Capital on Wages: Estimates For the United States, 1979-1990,” *Quarterly Journal of Economics*, 114, 907–940.

Garcia-Macia, D., C.-T. Hsieh, and P. J. Klenow (2019): "How Destructive is Innovation?" *Econometrica*, 87, 1507–1541.

Grossman, G. and E. Helpman (1991a): *Innovation and Growth in the Global Economy*, Cambridge MA: MIT Press.

——— (1991b): "Quality Ladders in the Theory of Growth," *Review of Economic Studies*, 58, 43–61.

Grossman, G. and E. Rossi-Hansberg (2010): "External Economies and International Trade: Redux," *Quarterly Journal of Economics*, 125, 829–858.

Hsieh, C.-T., P. J. Klenow, and I. Nath (2023): "A Global View of Creative Destruction," *Journal of Political Economy: Macroeconomics*, 1, 243–275.

Irwin, D. A. (2005): "The Welfare Cost of Autarky: Evidence from the Jeffersonian Trade Embargo, 1807-09," *Review of International Economics*, 13, 631–45.

Irwin, D. A. and P. J. Klenow (1994): "Learning-by-Doing Spillovers in the Semiconductor Industry," *Journal of Political Economy*, 102, 1200–1227.

Jaffe, A. B., M. Trajtenberg, and R. Henderson (1993): "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics*, 108, 577–598.

Jones, C. I. (1995a): "R&D-Based Models of Economic Growth," *Journal of Political Economy*, 103, 759–784.

——— (1995b): "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics*, 110, 495–525.

Juhász, R. (2018): "Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade," *American Economic Review*, 108, 3339–76.

Juhász, R., N. Lane, and D. Rodrik (2024): "The New Economics of Industrial Policy," *Annual Review of Economics*, 16, 213–42.

Kalouptsidi, M. (2018): "Detection and Impact of Industrial Subsidies: The Case of Chinese Shipbuilding," *Review of Economic Studies*, 85, 1111–1158.

Kleinman, B., E. Liu, S. J. Redding, and M. Yogo (2024): "Neoclassical Growth in an Interdependent World," *NBER Working Paper*, 31951.

Klette, T. J. and S. Kortum (2004): "Innovating Firms and Aggregate Innovation," *Journal of Political Economy*, 112, 986–1018.

Kortum, S. (1997): "Research, Patenting, and Technological Change," *Econometrica*, 65, 1389–1419.

Krugman, P. (1987): "The Narrow Moving Band, the Dutch Disease, and the Competitive Consequences of Mrs Thatcher: Notes on Trade in the Presence of Dynamic Scale Economies," *Journal of Development Economics*, 27, 41–55.

——— (1994): *Peddling Prosperity: Economic Sense and Nonsense in the Age of Diminished Expectations*, New York: W. W. Norton and Company.

Kucheryavyy, K., G. Lyn, and A. Rodriguez-Clare (2023): "Grounded by Gravity: A Well-Behaved Trade Model with Industry-Level Economies of Scale," *American Economic Journal: Macroeconomics*, 15, 372–412.

Lane, N. (2025): "Manufacturing Revolutions: Industrial Policy and Industrialization in South Korea," *Quarterly Journal of Economics*, 140, 1683–1741.

Little, I., T. Scitovsky, and M. Scott (1970): *Industry and Trade in Some Developing Countries*, Oxford: Oxford University Press.

Liu, E. (2019): "Industrial Policies in Production Networks," *Quarterly Journal of Economics*, 134, 1883–1948.

Liu, E. and S. Ma (2026): "Innovation Networks and R&D Allocation," *American Economic Review*, forthcoming.

Lucas, R. E. (1988): "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 3–42.

——— (1993): "Making a Miracle," *Econometrica*, 61, 151–272.

Mankiw, N. G., D. Romer, and D. N. Weil (1992): "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, 107, 407–437.

Melitz, M. J. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71, 1695–1725.

Melitz, M. J. and S. J. Redding (2014): "Heterogeneous Firms and Trade," in *Handbook of International Economics*, ed. by E. Helpman, G. Gopinath, and K. Rogoff, Amsterdam: Elsevier, vol. 4, chap. 1, 1–54.

——— (2015): "New Trade Models, New Welfare Implications," *American Economic Review*, 105, 1105–1146.

Mill, J. S. (1848): *Principles of Political Economy with some of their Applications to Social Philosophy*, London: John W. Parker.

Miller, C. (2022): *Chip War: The Fight for the World's Most Critical Technology*, New York: Scribner.

Mutreja, P., B. Ravikumar, and M. Sposi (2018): "Capital Goods Trade, Relative Prices and Economic Development," *Review of Economic Dynamics*, 27, 101–122.

Nickell, S. J. (1996): "Competition and Corporate Performance," *Journal of Political Economy*, 104, 724–746.

Ossa, R. (2016): "Why Trade Matters After All," *Journal of International Economics*, 97, 266–277.

Perla, J., C. Tonetti, and M. E. Waugh (2021): "Equilibrium Technology Diffusion, Trade and Growth," *American Economic Review*, 111, 73–128.

Ramondo, N. and A. Rodríguez-Clare (2013): "Trade, Multinational Production, and the Gains from Openness," *Journal of Political Economy*, 121, 273–322.

Ramsey, F. P. (1928): "A Mathematical Theory of Saving," *Economic Journal*, 38, 543–559.

Rapping, L. (1965): "Learning and World War II Production Functions," *Review of Economics and Statistics*, 47, 81–86.

Ravikumar, B., A. M. Santacreu, and M. Sposi (2019): "Capital Accumulation and Dynamic Gains from Trade," *Journal of International Economics*, 119, 93–110.

Redding, S. J. (1999): "Dynamic Comparative Advantage," *Oxford Economic Papers*, 51, 15–39.

Rivera-Batiz, L. A. and P. M. Romer (1991): "Economic Integration and Endogenous Growth," *Quarterly Journal of Economics*, 106, 531–555.

Romer, P. (1990): "Endogenous Technical Change," *Journal of Political Economy*, 98, 71–102.

Ruhl, K. J. (2008): "The International Elasticity Puzzle," University of Wisconsin, mimeo.

Sampson, T. (2016): "Dynamic Selection: An Idea Flows Theory of Entry, Trade and Growth," *Quarterly Journal of Economics*, 131, 315–380.

Schmookler, J. (1966): *Invention and Economic Growth*, Cambridge MA: Harvard University Press.

Schumpeter, J. A. (1942): *Socialism and Democracy*, New York: Harper & Brothers.

Searle, A. D. (1945): “Productivity Changes in Selected Wartime Shipbuilding Programs,” *Monthly Labor Review*, 61, 1132–1147.

Solow, R. M. (1956): “A Contribution to the Theory of Economic Growth,” *Quarterly Journal of Economics*, 70, 65–94.

——— (1957): “Technical Change and the Aggregate Production Function,” *Review of Economics and Statistics*, 39, 312–320.

Swan, T. W. (1956): “Economic Growth and Capital Accumulation,” *Economic Record*, 32, 344–361.

Ventura, J. (1997): “Growth and Interdependence,” *Quarterly Journal of Economics*, 112, 57–84.

Yi, K.-M. (2003): “Can Vertical Specialization Explain the Growth of World Trade?” *Journal of Political Economy*, 111, 52–102.

Young, A. (1991): “Learning by Doing and the Dynamic Effects of International Trade,” *Quarterly Journal of Economics*, 106, 396–406.

——— (1995): “The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience,” *Quarterly Journal of Economics*, 110, 641–680.