Globalization, Technology and Inequality

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Abstract

What are the effects of international integration on inequality, both between and within countries? The growing evidence that technology is the main determinant of wage and income differences may seem to imply that the forces of globalization only play a secondary role. Such a conclusion is however premature, in that it neglects the effect of international integration on technology itself. This opuscle summarizes recent and ongoing research studying how two important aspects of globalization, trade in goods and offshoring of production, shape the distribution of income when technological progress is endogenous. It discusses the theoretical foundations and the empirical support for various mechanisms through which international integration may change the incentive to develop and adopt new technologies and how this affects wages and the return to skill around the world.

1. Introduction

How much does it pay to get an education? Has the market value of holding a college degree changed over time? Does the cost of skilled labor vary across countries? Addressing these questions is important not only to understand the determinants of wages and income differences across individuals, but also to assess the role that skills and education play in the modern global economy. A first answer is contained in Table 1, which provides illustrative evidence on the level and recent evolution of the market value of education in a sample of both developed and developing countries.

Column (1) reports the college premium, defined as the relative wage of college graduate workers to high school graduates. As the table shows, in the year 2005 college-educated workers earned on average 1.58 times more than high school graduates. The table also documents important differences across countries. The premium is highest in the United States (1.9), while it is typically lower in continental Europe, which may suggest wage disparity to be larger in countries with less regulated labor markets. Even more importantly, column (4) shows that the college premium has changed over time. During the period 1980-2005, it increased on average by 12%, again with important differences across countries. In particular, the surge in wage inequality has been most pronounced in the United States, where the college premium soared by 44% to reach record-high levels. More generally, the increase seems to have been larger in Anglo-Saxon countries (such as Australia and Canada) and in emerging economies (such as Mexico and China) than in continental Europe.

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Unfortunately, we lack high-quality data on college premia for a large number of countries over long time periods. Nonetheless, most existing studies, using sometimes different measures, have uncovered similar trends: staring from the late 1970s, the wage gap between high-skill/high-educated and low-skill/low-educated workers, generically called “the skill premium,” has widened sharply. For instance, Epifani and Gancia (2008) find that during the 1980s the wage of non-production workers (usually employed in white-collar occupations) relative to production workers rose on average by 8% in a sample of 35 countries. Similarly, during the period 1990-2005, Parro (2011) reports an average increase of the skill premium of more than 7% in a sample of 26 countries.

Where does this increase in the value of education come from? To tackle this question, it is useful to recognize that the college premium is the relative price of workers with different educational attainments. As such, its market value should be determined to equate the demand coming from firms to the supply for educated worker, just like the price of any other good. Within simple conceptual framework, an increase in the college premium can be rationalized either with a rise in demand or a fall in supply. To have a sense of which of these two alternative scenarios is more plausible, a good starting point is to look again at the data. The difficulty in doing so, however, is that demand cannot be directly observed. On the other hand, data on the supply of college-educated workers is easily accessible and it turns out that looking at it is enough to infer what must have happened to demand.

Going back to Table 1, columns (2) and (5) reports, respectively, the fraction of working-age population with a college (or higher) degree and its change over the period 1985-2005. The salient fact from the data is that the supply of college educated workers has increased dramatically in all countries. On average, the increase amounts to a remarkable +174%. In itself, such a large surge in supply would have put a strong downward pressure of the wage premium. But this is not what happened, given that the college premium has grown in the majority of countries and has fallen slightly only in a few instances. Therefore, the only possible conclusion from these data is that the demand for college-graduate workers must have grown massively, at a rate faster than the increase in supply. Understanding what is behind this phenomenon has been the subject of an intense debate in the last decades.

Given the magnitude and the pervasiveness of the increase in demand for skill, it is no wonder that economists have turned to two major changes in the world economy to explain it: the revolution in the information and communications technology, and the dramatic globalization of markets for goods and services.

Proponents of the first theory have argued that the major technological innovations of the last decades, such as the development and wide diffusion of computers or more generally the Information and Communication Technology revolution, have increased the demand for skilled workers. This may have happened because high-tech equipment requires skilled workers to be produced and operated, but also because the use of computers is likely to boost the productivity of skilled workers relatively more than that of other workers. In both cases, these innovations are regarded as more complementary to skill, or, simply put, skill-biased.[1]

Advocates of the second hypothesis move from the observation that the increase in skill premia was concomitant with unprecedented advances in the process of global economic integration. For instance, Table 1 shows that trade openness, computed as the value of imports plus exports as a share of GDP, increased on average by 129% in the reported sample of countries. This reflects a global trend. From 1980 to the late 1990s, the volume of trade for the average country in the world rose from 59% to 74%, and the share of countries classified as open to trade by the Sachs-Warner index rose from 35% to 95%. Several major events contributed to this globalization boom. These include technological innovations that reduced the cost of distance, multilateral tariff reductions negotiated within the institutional framework of the WTO, the widespread formation of free-trade areas and a massive wave of liberalization episodes in developing countries such as Mexico, China and India.

Interestingly, the majority of studies report that the opening to international markets was often accompanied by an increase in skill premia. Two prominent examples already reported in Table 1 are Mexico, who liberalized its markets in the mid 1980s, and China, who started to opened its economy in the 1990s. In the two countries, the college premium increased by 30% and 20%, respectively. These empirical observations have led economists to investigate the effect of international trade on wage inequality. Until recently, however, the consensus view pointed at technology as the main culprit for the observed increases in skill premia. This conclusion was based both on direct evidence, for instance that the rise in the demand for skill has been greater in more computer-intensive industries (Autor, Katz and Krueger, 1998), but also on some difficulties that traditional trade models face when confronted with the data.

[1] This hypothesis has a long tradition. For example, Tinbergen (1975) was among the firsts to speculate that technological progress tends to increase the demand for more-educated workers and characterized the evolution of the wage structure as “race between technological development and access to education.”

In particular, the best-know channel though which international trade is expected to affect the relative price of skill applies when we consider the effects of market integration between a skill-abundant country, called for brevity the North, and a skill-scarce country, the South. In this case, the greater relative supply of skilled workers in the North leads in autarky to a relatively low skill premium, with the opposite holding in the South. When the two countries open their markets to trade, the North starts to export skill-intensive goods to the South and this raises the demand for skilled workers. In exchange, the South exports unskilled-labor-intensive goods to the North and this increases the demand for unskilled workers and leads to a lower skill premium in the South. Hence, looking at the real world through the lens of this model, unskilled workers in advanced countries such as the United States and Canada would be harmed by the competition from China and India, while the unskilled workers in the latter countries would benefit from selling their products in the large markets of the rich economies.[2]

While the logic of this argument, spelled out formally in the celebrated Heckscher-Ohlin and Stolper-Samuelson theorems, is impeccable, it suffers from at least two major drawbacks when applied to explain the recent evolution of skill premia. First, while the volume of trade between skill-abundant and skill-scarce countries has increased dramatically recently, it is often considered too small to have really large effects on the world economy. In particular, studies that computed the factor-content of U.S. import, which should capture the implicit competition from unskilled workers contained in imports, have found that trade can explain about one-tenth of the observed increase in the skill premium. Second, there is mounting evidence that inequality soared after trade liberalization in many skill-scarce countries, just the opposite of what the model predicts (e.g., see the studies surveyed in Goldberg and Pavcnik, 2007).

These and other observations have led several economists to believe that technology is the main determinant of wage differences and that the forces of globalization only play a secondary role. Such a conclusion is however premature, in that it neglects the possibility that international integration may

[2] This hypothesis has a long tradition too. Wood (1994) argued that competition from imports from low-wage countries would hurt unskilled workers in advanced countries. Freeman (1995) summarized this view in the title: "Are Your Wages Set in Beijing?"

affect technology itself. More precisely, there is a line of research that says "*it is trade, but it works through technology!* The purpose of this *opuscle* is to describe the research of proponents of this view, their successes and failures. In particular, Section 2 will discuss how trade integration between high-wage and low-wage countries (North-South trade), can affect the incentive to develop skill biased technologies and its impact on wages and the return to skill worldwide. Section 3 will focus instead on market integration between advanced countries (North-North trade). Section 4 will discuss the effects of a recent and important development in the global economy: the possibility to fragment the production process across different countries (offshoring).

2. North-South Trade and Skill-Biased Technical Change

The purpose of this section is to argue that trade with less developed countries can have a profound impact on wages, beyond what is suggested by static trade theory, through its effect on the direction of technical change. By changing relative prices, international trade can affect the incentives for developing innovations targeted at specific factors thereby systematically benefitting certain groups or countries more than others. To develop this argument, originally formalized in Acemoglu (2003), we first need to understand the main determinants of the skill bias of technological progress.

2.1. The Theory of Directed Technical Change

The theory of directed technical change aims at explaining how and why some innovations may increase the productivity and the reward of different factors asymmetrically. Examples of factor-biased innovations abound. For instance, economic historians typically agree that technological change during the eighteenth and nineteenth centuries was mostly unskilled-labor-biased, when factories and later assembly lines replaced artisan shops. On the contrary, as already mentioned, technological progress is believed to have been skill-biased during the last century, and this bias to have accelerated in recent years with the advent of computers and digitization. Models of directed technical change were introduced by Acemoglu (1998, 2002) precisely to explain these phenomena.

In the canonical model, workers belonging to two skill groups, H and L (high-skill and low-skill, respectively), produce two distinct and imperfectly substitutable goods. Technology is assumed to take a factor-augmenting form, meaning that technological change serves to either increase the productivity of H or L workers. More importantly, technological progress is assumed to be endogenous and to be driven by market incentives. In particular, following the endogenous growth literature (e.g., Romer, 1990 and Aghion and Howitt, 1992), introducing a new "machine," either L-augmenting or H-augmenting, is a deliberate and costly activity which is motivated by the prospect of the monopoly profits that the producer of the new machine will enjoy. In this framework, profit-maximization drives the direction of technical change, in the sense that when the profitability of, say, H-augmenting technologies is higher, we expect more innovations of this type to be developed.

But what determines the relative profitability of developing different technologies? A key result in Acemoglu (1998, 2002) is to show that this relative profitability depends on two contrasting effects:

1. The price effect: it is more profitable to develop technologies that are used to produce more expensive goods.

2. The market-size effect: it is more profitable to develop technologies that will be used by a larger number of workers.

These forces work in opposite directions because expensive goods (strong price effect) are often produced in limited amounts (weak market-size effect). The relative strength of the two forces depends on the degree of substitutability between the services of H and L workers. Intuitively, if these are perfect substitutes, they should have the same price, independently of the quantity produced. In this extreme scenario, the price effect disappears and only technologies augmenting the most abundant factor will be developed in equilibrium. As long as H and L produce imperfectly substitutable goods, instead, both H-augmenting and L-augmenting technologies will eventually be introduced at the same peace. But the ratio of existing H-augmenting and L-augmenting technologies, and therefore the relative productivity of different workers, will depend on the relative availability of each skill group. An important result in the theory of directed technical change is to show that, under fairly general conditions, the market-size effect dominates the price effect, in the sense that an increase in the relative supply of a factor always induces technological change that is biased in favor of that factor.

2.2. North-South Trade, Technology and Wage Inequality

Acemoglu (2003) considers the effect of trade opening between a skill-abundant North and a skill-scarce South in the benchmark model of directed technical change. A key assumption of the exercise is that the South lacks an effective system of protection of intellectual property rights and does not engage in innovation. As a result, new technologies are sold in the markets of the North only and are copied by the South. This implies that innovators in advanced countries do not make any profit from the use of their discoveries in poor countries. Of course, in reality U.S. technology firms do obtain royalties from the markets poor countries. Yet, the assumption is meant to capture in a simple (albeit somewhat extreme) way the evidence that infringements of intellectual property rights, such as piracy and counterfeiting, are much more prevalent in less developed countries.

For given technology, this model is a standard two-good, two-factor, two-country Heckscher-Ohlin model of the kind mentioned in the Introduction. The effect of trade opening in this class of models is to create a single market for goods with a relative price that depends on world (rather than local) production. Given that the world economy is more skill-scarce than the North and less skill-scarce than the South, the relative price of the skill-intensive good increases in the North and decreases in the South. The effect is larger the more different factor endowments are. This change in relative prices translates into a higher skill premium in the North and a lower one in the South, through the familiar logic of the Stolper-Samuelson theorem. In other words, the demand for skilled labor in the North increases due to export and the opposite happens in the South.

What happens to the skill-bias of technology once innovation reacts to trade opening? This depend, recall, on how the price and market-size effects are affected by trade. By assumption, the market size for innovation does not change, because inventors continue to sell their machines in the North only, where intellectual property is protected. For a given technology, however, trade increases the relative price of skill-intensive goods in the North. This change makes skill-complement innovations more profitable and leads to skill-biased technical change, which tend to increase the skill premium.

Is this effect sizable in practice? Acemoglu (2003) provides some back-of-the-envelope calculations to help to grasp the magnitude of the impact of trade on the skill premium in the US. Taking from Borjas, Freeman and Katz (1997) the observation that the unskilled labor content of U.S. import increased by 4% between 1980 and 1995 and under plausible calibrations, he finds that the overall impact of trade is to raise the U.S. skill premium by the same 4%. Given that, over the same period, the skill premium rose by roughly 20%, this simple exercise suggests that perhaps on fifth of this change can be attributed to trade with skill-scarce countries. Without directed technical change, instead, the impact of trade on the skill premium would be much smaller and would depend on the degree of substitutability between skilled and unskilled workers: using available estimates for this parameter, the effect would be between two and three times smaller.

2.3. The International Technology Diffusion and Inequality

Building on this line of research, in a recent paper by Gancia, Muller and Zilibotti (2013) we propose an alternative exercise to quantify the potential impact of globalization on inequality worldwide. The goal of this work is to construct and estimate a quantitative model of directed technical change that can shed light on the origins of wage differences across countries. The model extends the basic framework by adding capital and, more importantly, a mechanism of endogenous technology diffusion. The latter element is crucial for understanding technology differences across countries, which are known to be large empirically and to be a major determinant of wages.

In our model, technologically backward countries can adopt existing technologies at a cost that is a negative function of the distance from the world technology frontier. This assumption captures the so-called "advantage of backwardness" and implies that countries starting with inferior technologies, other things equal, will eventually catch up. Moreover, technology adoption is directed, precisely as innovation in advanced countries. Under these assumptions, skill-scarce countries have an incentive to adopt unskilled-labor-biased technologies, which complement their locally abundant factor. But they also have an incentive to adopt skill-biased technologies, because they are relatively abundant and therefore cheaper to adopt. Through these incentives for technology adoptions, the model therefore describes how skill-biased technical change originating in any country propagates endogenously worldwide.

Given data on the main factors of production (human and physical capital), the remaining parameters of the model are estimated to match income (GDP per worker) differences across countries in 2000 as close as possible. As it is relatively customary in the literature trying to account for GDP disparities, this exercise is initially done under the assumption that there are no trade linkages between countries. Despite the parsimonious specification, we find that the model can replicate the data remarkably well, a result that corroborates the underlying theory of endogenous technology diffusion. Next, with this calibration at hand, we use the equations of the model to study what happens after a change in some assumptions or parameter value. In other words, we do a "counterfactual" simulation of a hypothetical scenario.

Among the exercises we perform, we study the effect of a move from autarky in goods markets to free trade. Although such an exercise is admittedly extreme, it is nonetheless informative of how market integration shapes wage inequality both between and within countries once technology is allowed to react and diffuse endogenously. The outcome of this hypothetical scenario on income differences is depicted in Figure 1. The picture plots the income levels predicted by the model under free trade (the "counterfactual") on the vertical axis against the estimated income differences in autarky on the horizontal axis (GDP pw). All data points are relative to the U.S. income level and are plotted in a log scale (thus, a country with the same income per worker as the United States would have a score of log(1)=0).

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To understand the impact of trade, note that if the change in openness did not affect the relative income of countries in any way, then all the observations in the figure would line up exactly along the 45 degree line (the diagonal). As the picture shows, however, most of the observations are below the diagonal. This means that, after trade opening, countries are predicted to be on average poorer that the United States, because the score on the vertical axis (relative income with trade) is generally lower than that on the horizontal axis (relative income in autarky). In other words, trade opening widens income differences across countries.

The reason for this result is that, as in Acemoglu and Zilibotti (2001) and Acemoglu (2003), trade induces skill-biased technical change in the most advanced countries. This makes the world technology frontier less appropriate for the needs of skill-scarce countries, who lack the human capital required to operate complex technologies. In particular, GDP per worker relative to the United States decreases for the average OECD country from 0.68 to 0.41, while for non-OECD countries it falls from 0.19 to 0.10.

Next, Figure 2 illustrates the implication of the same experiment (trade opening) on the skill premium (rather than income disparities). The picture now shows the predicted change in the skill premium (vertical axis) against the income level of each country (on the horizontal axis). The main result is that opening up to free trade raises the skill premium in skill-abundant countries and lowers it in skill-scarce countries, as predicted by the Stolper-Samuelson theorem. This can be concluded by observing that predicted changes in the skill premium are positive for countries that are sufficiently rich (i.e., sufficiently to the right on the horizontal axis), and from the fact that richer countries tend also to be skill abundant.

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However, there is another effect. By inducing skill-biased technical change at the frontier, opening up to free trade also generates an upward pressure on the skill premium worldwide. As a consequence, wage inequality increases in the majority of countries, particularly in those that are already close to the world technology frontier. The conventional result that trade liberalization lowers inequality in skill-scarce countries holds only in the group of economies that are so far form the world technology frontier to be insulated from skill-biased technical change. For instance, in sub-Saharan countries, such as Mozambique, Tanzania and Rwanda, the skill premium falls on average by 42 percent, while wage inequality is found to rise in the Asian giants, India and China.

These results assume no international protection of intellectual property, so that trade opening changes relative prices, but not the market for new technologies. When trade liberalization is instead accompanied by international protection of IPR, the relevant market for new technologies becomes the world economy. Given the huge endowment of unskilled workers in many large developing countries, innovators now finds it profitable to develop technologies used by unskilled workers and this leads to worldwide fall in skill premia. Moreover, since all countries now use the same technologies, all wages become the same everywhere. Thus, trade liberalization becomes a powerful force promoting income convergence, but only when coupled with IPR protection.[3]

2.4. Related Literature and Open Questions

A key lesson from these models is that the skill-bias of new technologies is endogenous and is therefore likely to react to changes in the world economy. Recognizing this is a necessary step for a correct assessment of how the forces of globalization may affect wages. This insight was first noticed by Wood (1994), who argued that economic integration with less developed countries could lead to defensive skill-biased innovations in more advanced countries. Yet, Wood did not develop the mechanism through which such defensive innovations could occur. Building on the theory of Directed Technical Change, Acemoglu (2003) has been the first to formalize this argument and to obtain

[3] Overall, these results are in line with Acemoglu and Zilibotti (2001) and Bonfiglioli and Gancia (2008), who show in more specific models that trade opening with no global IPR protection may induce a wave of technological progress which favors disproportionately the North, while stronger IPR protection in the South can speed up technology transfer and reduce income differences.

an important amplification effect: under some conditions, trade integration with a skill-scarce country tends to increase the skill premium, not only by making skilled workers scarcer in the integrated economy, but also by inducing skill-complement innovations.

Yet, North-South models still face a number of difficulties when used to explain the recent evolution of wages. First, despite the magnification effect, the predicted increase in the skill premium remains small given the observed volume of North-South trade. For example, even factoring in the reaction of technology, we have seen that the factor content of U.S. imports can only explain a relatively small fraction of the observed changes in wage inequality up to the mid-1990s. The broad picture is unlikely to have changed much in more recent years. For example, in 2010, U.S. imports from China were about 2.5% of U.S. GDP only. These trade volumes are often considered too small to have a really large impact on technological progress in the U.S. economy, which is the world greatest innovator.

Second, although these models predict trade to increase inequality in some counties, they tend to imply the opposite outcome in some other countries. In particular, inequality should have fallen after trade liberalization at least in the most skill-scarce and technologically backward countries. Yet, as reported in Goldberg and Pavcnik (2007), most of the existing evidence points in the opposite direction: for example, existing studies show that trade liberalization in the 1980s and 1990s was followed by rising skill premia in countries such as Mexico, Colombia, Argentina, Brazil, Chile, India, and more recently China.

Finally, the result that North-South trade can potentially explain skill-biased technical change hinges crucially on the assumption that the South does not provide sufficient protection of intellectual property. While it is safe to assume that the effective degree of protection is relatively lower in less developed countries, the process of globalization has also been followed by a general tendency towards a strengthening of intellectual property rights. An example of this trend is the inclusion of the Agreement on Trade Related Intellectual Property Rights (TRIPS) in the statute of the WTO in 1994.[4]

[4] The TRIPS agreement establishes minimum standards of protection for several categories of IPRs and a schedule for developing countries to adopt them.

According to the models discussed in this section, these developments should encourage firms in the North to license more their technology to the South and would give powerful incentives to develop unskilled-labor-biased technologies, which would then tend to lower wage inequality.

3. The Skill-Bias of North-North Trade

The growing dissatisfaction with some of the prediction of Heckscher-Ohlin models have led many economists to dismiss the importance of North-South trade in explaining the growing skill premia worldwide and to look for other channels through which globalization may affect factor prices. A natural alternative is to consider models designed to explain trade between similar countries, which represent about two-thirds of the volume of world trade. This is the subject of the so-called “new trade theory”'. According to these models, developed originally in the 1980s, similar countries trade in similar products (a phenomenon referred to as "intra-industry trade") because firms produce differentiated goods under increasing returns to scale and because consumers enjoy having access to a greater variety of goods. Due to scale economies at the product level, countries specialize in the production of different varieties, while consumers prefer to spread their purchases across all goods, including those produced abroad. Intra-industry trade represents an overwhelming and growing share of world trade and is therefore a likely culprit for the increase in wage inequality. Yet, its distributional implications have long been overlooked.

The reason for this is that intra-industry trade is, by definition, trade in goods that are produced with similar factor-intensities. As a result, it is expected to leave relative factor demand and relative factor prices, such as the skill premium, unaffected. Likewise, the conventional wisdom is that trade integration between identical countries should not change the perceived relative scarcity of any factor and thus leave relative prices unaltered. In Epifani and Gancia (2006, 2008), we show that this seemingly plausible conclusion is, in general, wrong. On the contrary, under realistic assumptions, trade between similar countries is found to be skill-biased. Once again, the reason for this surprisingly result has to do with the interplay between technology and globalization.

Our theory builds on the observation that tasks performed by high-skill workers are different from those performed by low-skill workers, not only because of their higher cognitive content, but also for other important characteristics. First, skill-intensive activities often have the nature of fixed costs (think, for instance, of research, product development and marketing). This crucial feature implies that skill-intensive activities naturally generate economies of scale. To have an idea of how intrinsically related skill-intensive and scale-intensive activities are, it suffices to note that, in the empirical trade literature, an industry's ratio of non-production to production workers is often used to measure both skill-intensity and economies of scale (e.g., Helpman, Melitz and Yeaple, 2005).

Second, skill-intensive goods are typically highly differentiated, implying that the benefit from the possibility to introduce new variety of products is stronger in the skill-intensive sector. Intuitively, having the option to choose between different types of electronic equipments (from the iPod to refrigerators, serving very different purposes) is more valuable than having access to a variety of garments (all serving similar purposes).

These observations allow us to look at the distributional implications of intra-industry trade under a new perspective. Trade liberalization expands the size of markets and this in turn increases the demand for skilled labor for two related reasons. First, market size boosts skilled workers' productivity, because skill-intensive industries are subject to increasing returns to scale. Second, larger international markets offer a wider variety of differentiated products, thereby inducing people to shift their consumption habits towards these goods. Given that differentiated products are skill-intensive, the demand for skill increases too. In other words, while unskilled workers compete with each other in the production of the same goods, skilled workers can always find different market niches by inventing new differentiated varieties. These simple mechanisms suggest that ability is more important in large markets. As globalization is creating gigantic world markets, skilled workers benefit relatively more from this process.

3.1. Quantitative Implications and the Data

In Epifani and Gancia (2006), we provide a possible explanation for why skill-intensive sectors enjoy stronger increasing returns to scale together with supporting empirical evidence. In Epifani and Gancia (2008), instead, we try to measure the skill-biased scale effect and compare the resulting theory with the data. The quantitative effects we find are large. Under plausible calibrations, our model suggests that a 50% fall of trade costs between two identical countries can increase the skill premium by 10%, whereas full integration can raise it by up to 30%. A simple back-of-the-envelope calculation shows that scale effects in the U.S. economy over the years 1950-2000 can increase the skill premium by 8-15%. These numbers are substantially higher compared to those generated by the North-South models discussed in the previous section.

A second observation seemingly at odds with trade models is that commercial liberalizations seem to be followed by increases in the skill premium in many developing countries. Our model can rationalize this fact if the skill-biased scale effect is strong enough to overcome the factor proportions effect in skill-scarce countries. To see whether this is more than just a theoretical possibility, we use our model to study the episode of trade liberalization in Mexico. This case is of particular interest because, prior to 1985, Mexico could be considered a closed economy due to heavy policies of trade protection. In 1985, Mexico announced its decision to join the GATT and undertook major reforms leading to a reduction of tariffs by 45% and of import licenses by more than 75% within three years. During the same period, the skill premium rose by more than 17%.

The experience of Mexico is also interesting because its major trade partner is the United States. We can then perform the thought experiment of assuming that Mexico was in autarky in 1985 and asking what our model says about the effect of complete and instantaneous trade integration with the United States. Overall, we find that trade opening in the skill-scarce Mexico may lead to a considerable 15% increase in the skill premium, broadly matching actual data. These simple calculations suggest that the market size effect can play a significant role in developing countries that experience drastic trade liberalizations.

Finally, we confront our theory with the data. We start by discussing the existing evidence that skill-intensive products are more differentiated and also subject to stronger increasing returns to scale.[5] Next, we test for the empirical relevance of skill-biased scale effects using data for up to 68 countries observed between the early 1960s and the late 1990s. In particular, we propose various strategies to identify scale effects in three different datasets: a panel of economy-wide Mincerian returns to education, a panel of manufacturing skill premia and a panel of Gini coefficients of income inequality. Our results are strikingly consistent across datasets, samples and proxies for scale and wage inequality. Overall, they indicate that a doubling of market size can increases wage inequality by roughly 30 percent, a number roughly consistent with the theoretical predictions. These results suggests that a significant fraction of the observed divergence in the wage of high- and low-skill workers may be attributed to the growth of world markets due to globalization.

3.2. Related Literature and Open Questions

The idea that trade integration between similar countries may increase the return to skill has become increasingly popular. Earlier formalizations include Dinopoulos and Segerstrom (1999), who argue that larger markets increase the reward to innovation and therefore the demand for skill, and Neary (2002) and Thoenig and Verdier (2003), who argue that increased international competition makes skill-intensive technologies more profitable because they deter the entry of new firms. Matsuyama (2007), instead, assumes that the act of exporting requires skilled labor and develops a theory of biased globalization.

More recent work has focused instead on mechanisms that apply more specifically at the level of the firm. The common idea of Burstein and Vogel (2010) and Dinopoulos, Syropoulos and Xu (2011), for example, is that trade expands the average firm size and that this may affect the skill-premium because larger firms, for various reasons, demand more skilled workers.

[5] A second key assumption in Epifani and Gancia (2008) is that high- and low-skill workers be gross-substitutes. This implies that demand should shift in favor of the relatively more productive sectors. The vast majority of the available evidence is consistent with this hypothesis. See, for example, Ciccone and Peri (2005).

Supportive empirical evidence for this mechanism is presented in Bustos (2011). Unel (2010), instead, extends the results in Epifani and Gancia (2008) to a setting where firms have heterogeneous productivities.

Although all these models made important contributions, they still leave some unresolved questions. First, they are not specifically designed to explain the effect of trade on wages in less developed countries. While all the mechanisms just discussed imply that any trade liberalization would exert an upward pressure on the skill-premium, through skill-biased scale effects, the logic of the Heckscher-Ohlin and Stolper-Samuelson theorems would also apply, introducing a force in the opposite direction. As a result, the overall effect may turn out to be ambiguous.

Second, the model considered in this section suggests that trade between similar countries may increase the productivity of skilled workers and therefore the skill premium. Yet, the improved efficiency and gains from the access to foreign varieties typically ensure that trade should also make the unskilled workers better-off. In reality, however, Acemoglu and Autor (2011) document a decline of the real wage of U.S. unskilled workers in the 1980s and 1990s. The fall in real wages for unskilled workers in industrialized countries is hard to reconcile with mechanism based on North-North trade, which is usually beneficial to all types of workers, and/or the adoption of better technologies.

Finally, these models focus on trade in finished products and neglect the peculiarities of a new form of exchange that is becoming increasingly important: the fragmentation of the production process in stages that can be performed in different countries. This leaves the concern that these models may be missing some important feature of the recent globalization boom.

4. Offshoring, Technology and Wages

The rapid rise of offshoring, which involves many production and service tasks previously produced domestically being sourced from abroad, has been one of the most visible trends in the global economy over the last decades. Although precise measures of offshoring are difficult to come by, the magnitude of the phenomenon can be grasped by the surge in the share of imported inputs in total intermediate use in U.S. manufacturing, which has increased from about 6% in 1980 to over 27% today (Feenstra and Jensen, 2009). The production structure of Apple's video iPod gives a glimpse of these trends. Though designed and engineered in the United States, more than 99% of the production jobs created by this product are located abroad (Linden, Dedrick and Kraemer, 2011).

Despite its prevalence, the implications of offshoring for wages and skill premia are still debated. The iPod example illustrates its different potential effects. Like many other high-tech products, the iPod is designed in the United States and is made of component produced all over the world and assembled in China. Though most production jobs are offshored, a significant number of high-skill engineering jobs and lower-skill retail jobs are created in the United States, and more than 50% of the value added of the iPod is captured by domestic companies. With more limited offshoring, some of the production jobs may have stayed within the U.S. borders, increasing the demand for the services of lower-skill production workers. But this would have also increased the cost and price of iPods, reducing employment not only in engineering and design occupations but also in retail and other related tasks. In sum, one of today's most critical questions on offshoring, is whether U.S. innovations are benefiting American workers (and which type of workers), or are mainly creating jobs overseas.

In Acemoglu, Gancia and Zilibotti (2012), we study the impact of offshoring on wages of high- and low-skill workers of different types through its effect on technological progress. Returning to the example of Apple products, the variety of iPods may not have been profitable to introduce and develop if labor costs were higher -- as they would have been without offshoring. More importantly, iPods and other products may have been designed differently in the face of these different labor costs.

To provide a framework for studying these issues, we introduce directed technological change into a model of offshoring. As in the basic framework discussed in the previous sections, there are two final sectors, one employing high-skill workers the other employing low-skill workers. In each of these two sectors, production requires labor to be allocated across a variety of intermediates or “tasks.” Technical progress takes the form of the introduction of new intermediates (either in high-skill or low-skill sector). However, the production of some of these intermediates can now be relocated across countries to take advantage of lower wages.

In particular, offshoring takes the form of some of these tasks being transferred from a skill-abundant “West” to a skill-scarce “East” at a cost. Profit maximization determines not only how much offshoring will take place in equilibrium, but also the rates at which the productivities of both the high- and low-skill sectors improve. An important implication highlighted by our model is that offshoring has an efficiency-enhancing effect, because it reallocates production towards countries where wages are lower. This efficiency effect is stronger when there is little offshoring, because the wage gap between the West and the East is greatest in this case. By increasing the demand for labor in the East, greater offshoring closes this gap.

4.1. Offshoring and Wages without Technological Change

Though the main focus of Acemoglu, Gancia and Zilibotti (2012) is on innovation, the model also highlights the key channels through which offshoring affects wages for given technology. In particular, for given technology, the impact of offshoring on the skill premium can be decomposed into two types of effects.

First, as in standard trade models, offshoring exposes Western workers to the competition of cheap labor in the East. Given that Eastern workers are mostly low skill, this effect tends to reduce the wage of unskilled workers in the West. This standard mechanism works through both the reduction of the relative price of the low-skill good and the displacement of Western workers whose jobs are relocated the East. The overall implication is a reduction in the demand for unskilled labor and an increase in the skill premium in the West.

Second, there is another force working in the opposite direction. Recall that offshoring increases the overall efficiency of a sector by lowering average production costs (thanks to cheap labor in the East). This effect, which is based on the complementarity between Western and Eastern workers, is more pronounced in the low-skill sector, where there are more offshoring opportunities. If this effect is strong enough, it can increase the demand for unskilled workers in the West and lower the skill premium.

Thus, through the efficiency effect, offshoring can in some cases benefit precisely the low-skill Western workers whose jobs move abroad, both in absolute terms and also relative to skilled workers. However, the model shows that for realistic parameter values this effect is likely to be dominated by the direct competition with low-wage Eastern workers. Moreover, the model also suggests that the efficiency effect is destined to disappear, as more offshoring compresses the wage gap between the West and the East.[6]

4.2. Offshoring and Wages with Technological Change

How does technological progress react to offshoring? Consider, for simplicity, a case in which offshoring can only take place in the low-skill sector (e.g., there are no skilled labor in the East). As in the benchmark model of Section 2.1, the effect of offshoring on the incentive to introduce different technologies work through price and market size effects.

First, by raising production of the low-skill good, offshoring increases the relative price of skill-intensive products, thereby inducing skill-biased technological change. Counteracting this, however, offshoring makes it possible to employ Eastern workers, thereby expanding the market for technologies used by unskilled labor. This market size effect tends to induce low-skill innovations. Interestingly, which force dominates depends on the level of offshoring and on parameters. Focusing on the most realistic case, we show that the price effect dominates for low levels of offshoring. Thus, greater offshoring opportunities initially induce skill-biased technological change. If the level of offshoring is already high, however, the opposite pattern obtains.

The reason for this switch in the direction of technological progress is that the price effect, which triggers skill-biased technical change, is fueled by the efficiency gains from offshoring, which in turn depend on the wage gap between the East and the West. As already discussed, this effect is strong initially, but it eventually disappears as more and more offshoring raises the

[6] This efficiency effect is related to Grossman and Rossi-Hansberg's (2008) productivity effect, but it differs in that it is more pronounced when there is little offshoring and thus a large wage gap between the East and the West.

wages the East. These results can be summarized saying that the opportunity to produce in the East does not provide strong enough incentive to innovate in the low-skill sector as long and the unskilled wages in the East are too low. Yet, if the process of offshoring continues, Eastern wages will be become high enough to attract low-skill innovations.

The impact of offshoring on technology yields new implications for the evolution of the skill premium. Not surprisingly, offshoring first increases wage inequality in the West, both through its direct effect and by triggering skill-biased technical change. However, as offshoring continues, technical change will eventually change direction and may even lower the skill premium.

These results can help to explain the observed changes in the college premium and unskilled wages, and can also overcome some of the limitations that previously discussed models face when compared to the data. The first wave of offshoring took place in the 1980s, and, as predicted by the model, it was associated with a decline in the real wages of unskilled workers in the United States. As offshoring continued to expand in the late 1990s and 2000s, however, unskilled wages stabilized and began rising (e.g., Acemoglu and Autor, 2011). Moreover, since the negative effect of offshoring on the wage of unskilled workers is predicted to be strongest when the extent of offshoring is limited, the model is immune from the criticism that low volumes of trade in intermediate inputs cannot have significant labor market effects. The model is also broadly consistent both with Bloom, Draca and Reenen (2011), who find that the surge of imports from China from the late 1990s encouraged investments in information technology across European countries and with Autor, Dorn and Hanson (2012), who show that it also reduced the demand for labor in the United States.

4.3. Offshoring Skill-Intensive Tasks

What is the effect of offshoring on the skill premium in the East? To answer this question, Acemoglu, Gancia and Zilibotti (2012) extend the basic model by adding skilled labor in the East and the opportunity to offshore skilled intermediates as well. The exercise is important also to capture the recent boom in service offshoring, which was made possible by digitization. This new phenomenon affects activities such as finance and accounting services, call centers, marketing, sales services and software development, which are usually performed by relatively skilled workers.

The generalized model confirms the main findings discussed so far. More interestingly, however, it yields a new and important result: starting from low levels, offshoring increases wage inequality both in the West and the East simultaneously.

This surprising result is driven by the assumption that the cost of offshoring is the same in both sectors. In turn, this implies that the value of offshoring, which is proportional to the East-West wage difference, must also be equalized. This is accomplished by a higher offshoring rate in the unskilled sector, so as to increase the relative demand and hence the wage for unskilled workers in the East. It follows that the skill premium in the East follows the same evolution as that in the West: it increases initially with offshoring and may eventually fall when the level of offshoring is sufficiently high.

This result can therefore contribute to explaining why trade liberalization in less developed countries has been associated with growing skill premia and is consistent with the specific evidence in Sheng and Yang (2012), who find that the processing exports and FDI explain a large fraction of the recent increase in the Chinese college wage premium.

4.4. Related Literature and Open Questions

The potential negative effects of offshoring on the wages of lower-skill workers in advanced economies have been originally emphasized, in models with exogenous technology, by Feenstra and Hanson (1996 and 1999), Deardorff (2001, 2005) and Samuelson (2004). Samuelson, for example, famously pointed out that offshoring could lower Western income if it implies the transfer of knowledge to less advanced, lower-wage economies and thus the erosion the Western technological advantage.

Counteracting this effect are the efficiency gains due to offshoring, which have been stressed by several recent models, including Grossman and Rossi-Hansberg (2008) and Rodriguez-Clare (2010). In particular, Grossman and Rossi-Hansberg (2008) where among the first to argue that the efficiency gains due to offshoring in the low-skill sector could raise the demand for unskilled products so much as to lower the skill premium. They also argued that a satisfactory description of the phenomenon of offshoring requires a "task-based" approach, where the key distinction is between routine occupations, which can easily be relocated to other countries, and non-routine tasks, which are difficult to offshore.

Feenstra and Hanson (1996 and 1999) and Trefler and Zhu (2005), instead, argued that the relocation of firms from advanced to developing countries triggered by the removal of barriers to capital and technology flows can lead to a generalized increase in the skill premium. This can happen when the offshored jobs are skill-intensive relative to the average occupations in developing countries, but low-skill-intensive relative to the standards in advanced countries. If this is the case, offshoring can increase the relative demand for skill simultaneously in the source and the destination country.

Despite the recent boom, the literature on offshoring is still in its infancy. One of the key difficulties in this line of research is that defining and measuring offshoring is not easy. As a result, models studying this phenomenon are difficult to test empirically. Part of the problem hinges on the many facets of offshoring. For example, the sourcing of input goods from other countries can take various forms, which evolve continuously with technological advances, and can happen within multinational firms or through independent suppliers (as stressed by Antras and Helpman, 2004). In turn, different modes of organization are likely to have different implications for wages and technology. The challenge for the literature is therefore to explore systematically these implications both in theoretical models and in the data.

5. Conclusions

This *opuscle* has summarized recent research studying how two important aspects of globalization, trade in goods and offshoring of production, shape the distribution of income when technological progress is endogenous. It has discussed the theoretical foundations and the empirical support for various mechanisms through which international integration may change the incentives to develop new technologies and how this affects wages and the return to skill around the world.

It is fair to conclude that we know by now various mechanisms through which trade integration -- both between similar and dissimilar countries -- can raise the relative demand for skilled workers. We have also seen that technological progress can often amplify these effects by inducing the development of skill-complement innovations. Although it is difficult to discriminate empirically between alternative explanations and to disentangle the distinct role played by trade and technology, the broad stylized fact seems to be consistent with the view that trade between similar countries and offshoring of tasks to low-wage countries are at least partly responsible for the rising skill premia worldwide and for the deteriorating fortunes of unskilled workers in advanced economies.

This line of research has made a significant progress at understanding the interplay between trade and technology. To some extent, the success of the basic approach was due to a number of simplifying assumption. But tractability comes at the cost of leaving possibly important factors out of the picture. In particular, one of the most restrictive assumptions of all the models reviewed so far is the existence of two types of workers only, which prevents them from studying the evolution of the entire wage distribution.

Yet, Autor, Katz and Kearney (2008), and Acemoglu and Autor (2010), argue that a fully satisfactory account of recent changes in the U.S. wage structure requires more than two skill groups, to account for differential changes at the bottom, middle and top of the earnings distribution. Moreover, there is evidence that a significant part of the change in the relative demand for skilled workers has occurred within rather than between occupations or educational groups, and that wage dispersion between plants and firms is also empirically important.

Recent papers aimed at studying trade and offshoring in the presence of a wider heterogeneity among workers include Manasse and Turrini (2001), Yeaple (2005), Antras, Garicano and Rossi-Hansberg (2006), Ohnshorge and Trefler (2007), Costinot and Vogel (2010), Helpman, Itskhoki, and Redding (2010, 2011), Monte (2011). Although these models provide a richer description of the entire wage distribution, they also tend to be analytically less tractable. As a result, studying the interplay between globalization and technology in this class of models remains a challenge for future research.

Finally, before concluding, it is important to note that the focus of this *opuscle* was confined to the discussion of positive theories. That is, models designed to provide a description and an explanation of important trends in skill premia that are observed in the world economy. Whether the degree of wage inequality generated by trade, technological or any other factor is optimal or desirable according to some welfare criterion or whether it calls for some corrective policy is instead a normative question that goes beyond the scope of these pages. Yet, the models discussed in this work should provide a useful foundation for any policy analysis related to the labor market effects of globalization.

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Table 1: College Premium, Education and Openness

	Level in 2005			% Change 1980-2005		
	(1)	(2)	(3)	(4)	(5)	(6)
Country	College Premium	College Completed	Openness	College Premium	College Completed	Openness
Australia	1,72	20,6	40,8	19	20	91
Austria	1,38	10,7	104,1	-1	410	94
Canada	1,55	31,9	72,3	15	182	82
China	1,50	3,2	65,1	20	433	294
Denmark	1,47	11,4	93,2	1	27	98
Finland	1,53	15,0	79,4	-7	124	91
Italy	1,34	6,7	51,9	3	148	86
Japan	1,49	21,5	27,4	4	142	84
Mexico	1,80	12,5	55,1	30	221	262
Netherlands	1,58	16,8	131,3	-9	143	108
Spain	1,68	15,7	56,9	27	241	201
United Kingdom	1,61	11,9	56,5	5	98	77
United States	1,90	31,0	26,5	44	71	116
Average	**1,58**	**16,1**	**66,2**	**12**	**174**	**129**

Notes: Data on the college premium are from EU-KLEMS, Krueger et al. (2010) and Ge and Yang (2012). The change in the college premium for China refers to the period 1992-2007. Educational attainment and openness are from Barro-Lee and the Penn World Tables 7.1.

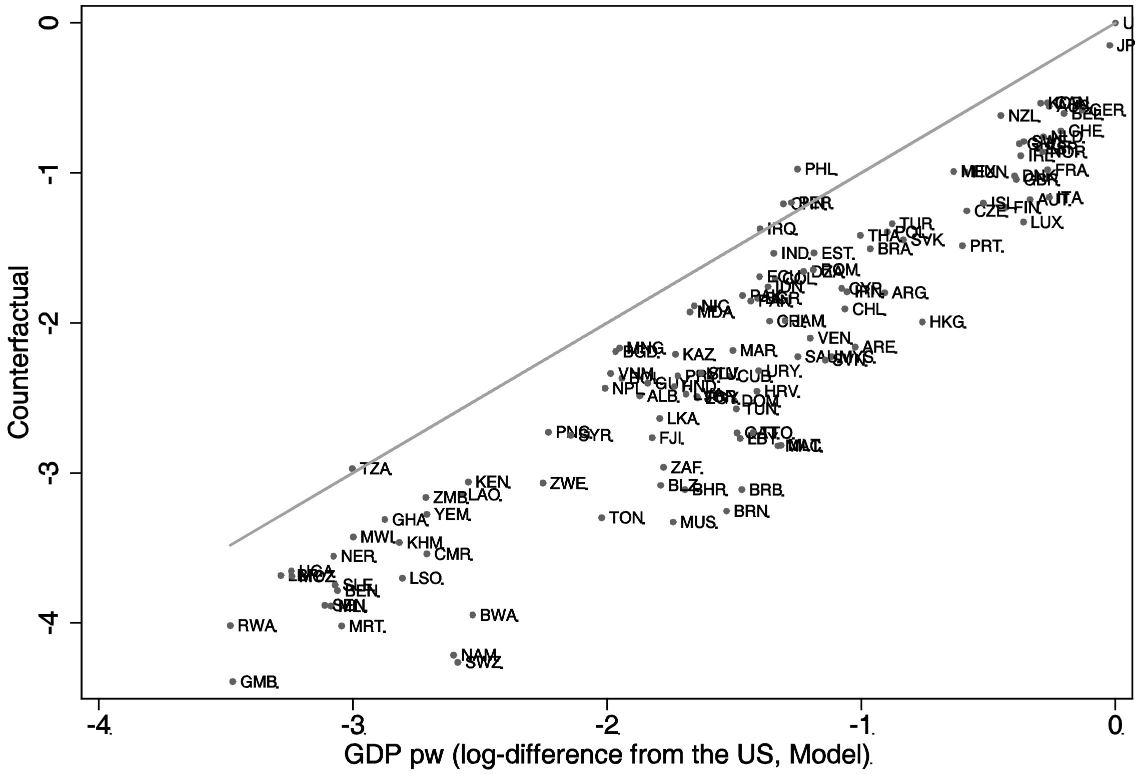

Figure 1: GDP pw, benchmark to free trade counterfactual.

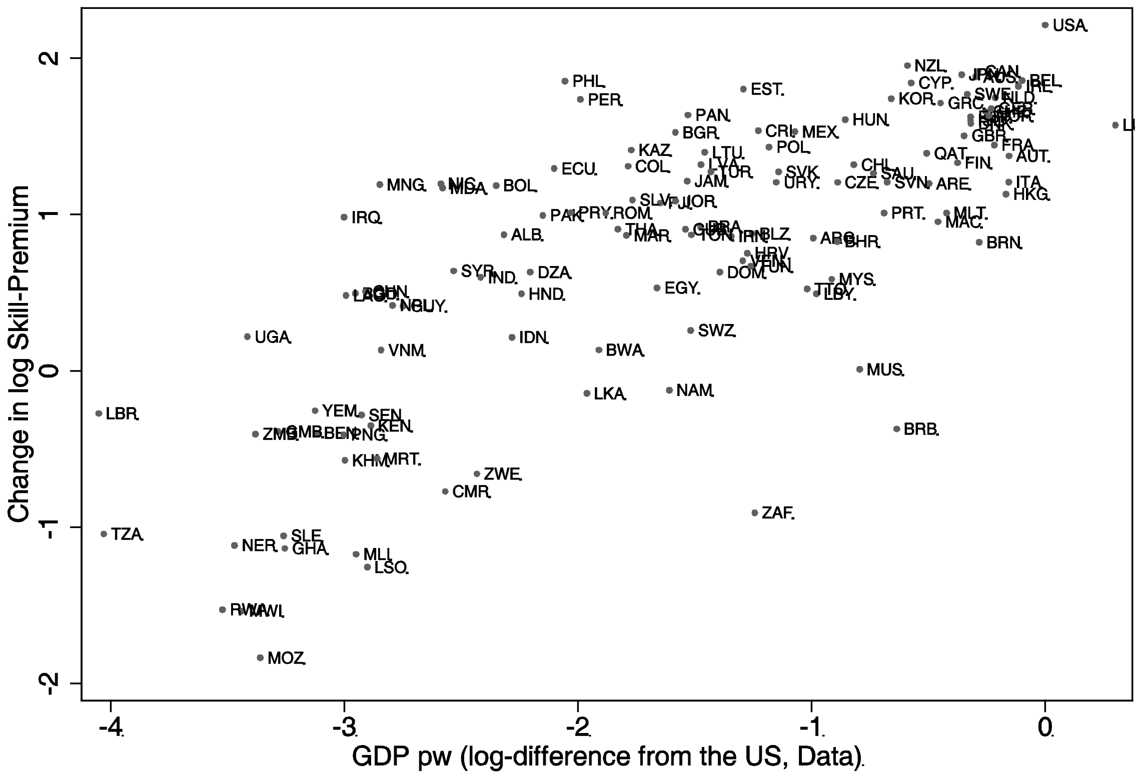

Figure 2: Change in skill Premium, benchmark to free trade counterfactual.