The endogenous skill bias of technical change and wage inequality in developing countries

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Abstract

This paper draws on existing empirical literature and an original theoretical model to argue that globalization affects the extent to which technology adoption in developing countries favors skilled workers. Developing countries are experiencing technical change that is skill-biased because imported skill-biased technologies are becoming relatively cheaper. Free trade induces technology that favors skilled workers in skill-abundant developing countries and that favors unskilled workers in skill-scarce developing countries, and therefore amplifies the predicted wage effects of trade liberalization. Increased skill supply further biases technical change in favor of skilled labor. These features aid our understanding of the observed rises in inequality within developing countries, the absence of a significant downward effect of expanded educational attainment on skill premia, and the differential effects of trade liberalization on inequality.

I. INTRODUCTION

Inequality is a pervasive feature of the world's economies. Over the past generation, developed and developing countries alike have experienced greater inequality amidst unprecedented increases in educational attainment and trade openness. This is puzzling; an increase in the supply of skilled labor should reduce its price, and trade liberalization in developing countries was supposed to have the same effect.

One explanation offered for the period of increasing income inequality worldwide is that it has been a time of unmatched technological progress and capital deepening that increased the relative demand for skilled workers. The argument finds support in the pervasive nature of such inequality patterns (Berman et al, 1998) and developments like the Information and Communications Technology revolution (Katz & Autor, 1999). However, capital deepening and Total Factor Productivity (TFP) growth were insufficient to account for the observed changes in inequality (Berman & Machin, 2000; Acemoglu, 2002). Furthermore, the conditional correlation between trade and inequality is zero or positive in Middle-Income Countries (MICs) and negative in Low-Income Countries (LICs). The sign of the correlation would be consistent with extensions to the Heckscher Ohlin Stolper Samuelson (HOSS) predictions if we accept that many MICs are skill-abundant relative to the global average, but it appears that the standard HOSS mechanism alone makes a relatively limited contribution to the impact of trade on skill premia (Chusseau, Dumon & Hellier, 2008).[2]Moreover, the data suggest the correlation of inequality and the quantity of skills is close to zero after allowing for exogenous trends.

What else can help explain these patterns? This paper presents endogenous skill-biased technical change (SBTC) in developing countries as a contributing factor. It extends the conceptual framework of directed technological change in advanced countries introduced by Acemoglu (1998) and others. An essential part of the proposed explanation is that *technological change is not necessarily skill-biased and can favor either skilled or unskilled workers*. The decision to acquire a technology that favors skilled workers depends on that technology's relative profitability. The profitability of a skill-biased machine depends on the market for that machine, which in turn depends on the availability of skilled workers and on the price of the good produced with that machine; the price can rise or fall after opening up to international trade, depending on the skill endowment. While many papers emphasize the endogeneity of the quantity of technology acquisition to prices and other factors (Burstein, Cravino & Vogel, 2012), which has been skill-biased, our emphasis here is on the endogeneity of the extent of the skill-bias.

The observation that the skill-bias of technological change responds to endowments and other

[2]Readers interested in the relative employment fortunes of skilled and unskilled workers in developing countries could refer to Conte & Vivarelli (2011).

local conditions is consistent with countries adopting appropriate technology (Atkinson & Stiglitz, 1969) and is supported by formal analysis (Caselli & Coleman, 2006) and by examples from history. Treating the bias of technical change as endogenous allows one to predict that a rise in the supply of skilled labor can induce SBTC and hence increase the relative demand for skilled labor. A MIC that is skill-abundant relative to the world and opening up to trade would experience a rise in the price of skill-intensive products and would hence have an incentive to acquire skill-biased technologies. Conversely, skill-scarce LICs would experience technological change that favors unskilled workers and would see a fall in the skill premium after opening up to trade.

As noted in a recent survey (Kurokawa, 2014), although trade-based explanations for rising wage inequality are partly overcoming initial criticisms, further work is needed on understanding links between trade and technical change. In addition, developing countries tend to acquire their technologies from developed countries. The nature of R&D in rich countries is also endogenous, but has been skill-biased in recent times. This affects the skill-bias of technologies available to poorer countries and thus tends to make developing countries acquire skill-biased technologies irrespective of their local conditions (Berman & Machin, 2000). Globalization in a broader sense – liberalization of trade in goods and access to foreign technology – therefore plays an important role in the extent to which technical change is skill-biased.

Section II presents suggestive data on the relationships between inequality, the skill endowment, and trade openness before presenting evidence that the skill-bias of technical change is endogenous in developing countries. Section III introduces a formal model of the arguments. In line with prior work on developed countries (Acemoglu, 2002a; Acemoglu, 2003; Kiley, 1999), we use an endogenous growth model with two types of workers: skilled and unskilled. Our emphasis on developing countries means that, instead of incurring R&D costs, firms pay for the monopoly licence to acquire a technology and import machines using that technology from abroad in order to sell them domestically. An implication of this is that the amount of induced SBTC, and hence of inequality, is a function of the rate at which more advanced technologies get more expensive. Furthermore, developing countries are often small and have limited or no impact on the relative price of skilled and unskilled products. This also has quantitative implications for the extent of SBTC and wage inequality responses.

Section IV deploys the model. First, it shows formally how SBTC in developed countries leads to SBTC and higher wage inequality in developing countries in thsi framework. Second, it shows that the HOSS effects on inequality in a skill-abundant small economy opening up to trade are amplified by induced technical change. When two large developing economies open up to trade, there are again amplified effects on inequality relative to HOSS, but these are smaller than in the SOE case.This amplification is important because, even when traditional endowment-based models correctly predict the sign of the impact of trade on inequality, they typically generate a small quantitative impact. Third, in a small open economy (SOE), a rise in skill supply unequivocally increases the skill premium. Furthermore, consistent with prior work on the closed economy, increased skill supply leads to higher inequality if the elasticity of substitution between skilled and unskilled labor is sufficiently high in this framework. Section V concludes with some policy implications.

The emphasis here is on a unified framework for thinking about endogenous SBTC in developing countries and its part in explaining the pervasive increases in inequality, the seeming lack of a correlation with the quantity of skills, and the differential effects of trade in MICs and LICs. However, we recognize that this emphasis comes at the cost of excluding many legitimate and important individual explanations.

II. EMPIRICAL BACKGROUND

This section describes patterns of wage inequality and then describes three factors that affect the extent to which technical change is skill-biased.

A. Patterns of Income Differentials

This section documents three stylized yet potentially surprising patterns for inequality in developing countries. The linear projections in Table 1, to which we attach no causal interpretation, summarize these patterns. First, inequality increased for all developing countries over time. Second, and surprisingly, there seems to be no correlation between inequality and the proportion of the skilled population. Third, the correlation between inequality and openness appears to be negative for LICs but zero or positive for the Lower-Middle-Income Countries (LMICs) and Upper-Middle-Income Countries (UMICs).

The first three columns of Table 1 distinguish between LICs, UMICs, and LMICs using an index of *household income inequality*; this is because there is a panel with a comfortable number of observations for each country income group. However, the formal model refers to the skill premium, namely the ratio of skilled to unskilled wages. Goldberg & Pavcnik (2007) note that observed changes in the skill premium are generally but not always reflected in other measures of income inequality. Therefore, columns 4 and 5 describe empirical relationships that more closely match the theory by representing inequality by the *skill premium,* but this is at the cost of limited observations in a single cross-section of data. In particular, there are insufficient observations for a separate linear projection for LICs. The method and data are described in the Appendix. Although the data are limited, they provide a basis for further discussion in the context of other studies of wage patterns.

Table 1: Projections of Inequality on Education, Trade and Time for Developing Countries

Dependent Variable:	EHII[1]			Skill Premium[2]	
Countries:	LIC	LMIC	UMIC	LIC,LMIC	UMIC
Skilled Proportion	-0.204*	0.0607	-0.0577	0.0668**	0.027
Standard error	[0.0980]	[0.0706]	[0.0904]	[0.0298]	[0.0362]
Trend	0.109	0.210***	0.328**		
Standard error	[0.0945]	[0.0701]	[0.135]		
Trade/GDP share (Goods)	-6.312**	0.0377	1.898		
Standard error	[2.158]	[1.166]	[3.066]		
Open Dummy				0.0231	0.207*
Standard error				[0.0502]	[0.114]
Constant	-143.5	-375.1**	-616.8**	0.398***	0.292***
Standard error	[193.5]	[137.9]	[269.3]	[0.0353]	[0.0658]
R^2	0.36	0.23	0.27	0.18	0.20
N	38	62	60	26	17
Countries	15	20	15	26	17

[1] EHII is index of household income inequality and projected on the log of the proportion of the population who have completed at least primary school, the log of goods trade as a share of GDP, and a five-year trend term using country fixed effects in a panel. Regressions are run for Upper-Middle-Income (UMIC), Lower-Middle-Income (LMIC) and Low-Income (LIC) countries.[2] Skill Premium is the log of the skill premium for people with at least primary school, calculated based on Mincerian earnings estimates. It is projected on the skilled proportion and an openness dummy for countries with high trade/GDP shares. Projections are run for LICs/LMICs and UMICs. *, ** and *** denote significance at 10%, 5% and 1% based on robust standard errors in brackets.

Inequality Over Time

It is well documented that there has been a rise in inequality in developed countries over the last generation (Chusseau et al, 2008). Table 1, which refers to developing countries, has positive trend terms representing five-year increments from 1980 to 2000. The coefficient is lower for LICs and, of the five individual countries that experienced a fall, three were LICs. Of the 40 countries with sufficient long-range data, 34 experienced increases in inequality over the period and one experienced no change. As documented in Meschi & Vivarelli (1999) and Behar (2011) with data since the 1960s, the increase lagged that in developed countries and became rapid in the mid-1980s. Behar (2009) presents similar patterns over time based on the skill premium in a limited set of countries. Berman & Machin (2000) also document how the rise in inequality has been pervasive and that the rise in developing countries lagged that in the rich world. This suggests that some driver external to the characteristics of each developing country is pushing inequality upwards, and we will present the case that this is skill-biased R&D in developed countries. .

Inequality and Schooling

The rise in inequality has coincided with a rise in educational attainment in developing countries. For example, the median proportion of people who completed primary school rose by approximately half, and 39 out of 40 countries increased their average years of schooling between 1965 and 2000 (Behar, 2011). Table 1 suggests expanded educational attainment has no robust association with household income inequality or wage premia.[3] The absence of a correlation between income differentials and the quantity of skills is cause for concern given that education is often associated with economic growth but also seen as a way to reduce inequality. By reducing the relative scarcity of skilled labor, education is supposed to reduce its relative price.[4] However, there are a number of reasons why this may not be so,[5] including the possibility that skill supply creates its own demand. As has been argued by Acemoglu (1998) and Kiley (1999) for developed countries, we will argue that increased skill supply makes the market for technologies that favor skilled workers more attractive and hence induces SBTC in developing countries.

Inequality and Trade

Since World War II, the share of goods traded internationally has risen dramatically. While initially dominated by trade between industrialized countries, more recent surges have been a South-South trade phenomenon (Gourdon, 2011; Hanson, 2012). Table 1 suggests that LICs that opened their economies to trade more had a smaller rise in inequality. However, LMIC exports have no relationship with inequality. The experience among UMICs varied, as shown by the large standard errors, but those that increased trade more tended to have a larger rise in inequality. Other results, available on request, show that there was no correlation for the developing countries as a whole, which is consistent with Meschi & Vivarelli (2009). Furthermore, Table A1 in the Appendix shows similar results using alternative measures of trade openness.

The linear projections on cross-section data (Table 1, columns 4 and 5) use an alternative measure of openness for robustness, namely the Sachs & Warner (1999) dummy distinguishing between more- and less-open countries. The results suggest that more open UMICs tended to have higher wage premia, but that more openness in LICs and LMICs is not associated with wage premia.

The standard two-country Heckscher Ohlin Stolper Samuelson (HOSS) model predicts a fall

[3]These results, like those in Caselli & Coleman (2006), use the completion of primary school as the measure of attainment. Behar (2009, 2011) documents multiple specifications using cross-sectional, panel and time-series data that reveal little or no correlation between measures of income differentials (like wage premia or household inequality) and measures of educational attainment (like the average years of schooling and the proportions of skilled labor, where skilled labor can be defined at various cutoff levels of education), regardless of the country's stage of development.

[4]From a theoretical perspective, the positive coefficients in columns 4 and 5 can be problematic because most derivations would imply a negative elasticity of substitution between the factors in a constant elasticity of substitution production function.

[5]See for example Knight & Sabot (1987), De Gregorio & Lee (2002), Martins & Pereira (2004), and Machin & Manning (1997).

in the wage premium in developing countries. Not only is standard HOSS inconsistent with Table 1, it is also inconsistent with the case study evidence, mostly from MICs, that openness increased wage inequality (Goldberg & Pavcnik, 2007). However, HOSS can be modified in various ways to change the qualitative natrue of the predictions (Kurokawa, 2014). For example, a novel modification intoduces inferior goods to such a model such that trade can pull people into a poverty trap (Bond, Iwasa & Nishimura, 2013). Other modified versions of HOSS allow for more than two levels of skill abundance and possibly a continuum, which would permit UMICs to be skill-abundant relative to LMICs and LICs but not relative to advanced countries. In this setting, HOSS would predict a fall in the relative price of skilled goods and in the skill premium for those few but populous countries abundant in unskilled labor and the opposite effect for the rest. This is consistent with Table 1 and with proposals by others that the opening up of the Chinese economy in particular made many countries skill-abundant relative to the global average. Trade liberalizations in Latin America, which tended to be associated with increased skill premia there, coincided with the integration of many LICs into the global economy (Davis, 1996; Wood 1997; Wood & Mayer 2011). Fajnzylber and Fernandes (2004) find that increased levels of international integration were associated with increased demand for skilled labor in Brazil but with decreased demand in China. Tunisia's proximity to Europe makes it trade a lot with that continent, rendering it relatively abundant in unskilled labor; recent evidence indicates that increased trade led to a fall in inequality there (Ben Salha, 2012).

SBTC of the form discussed has long been advanced as an alternative explanation[6] to trade for the rises in inequality in both developed and developing countries alike. However, there is evidence that trade and technological change are themselves linked in developing countries. There are a number of mechanisms for trade to affect technological change yet further exploration of these links is needed (Kurokawa, 2014). We will emphasize how trade can affect the skill-bias of the technology imported. In particular, trade liberalization changes the relative price of skilled and unskilled products and hence the relative profitability of producing skill-biased technologies.

B. Drivers of Skill-biased Technical Change

Intrinsic versus Endogenous Skill Bias

Why has technical change favored skilled labor? One response is that technical change is skill-biased by nature because machines complement skills (Griliches, 1969) or because new technologies require skilled people to implement them (Nelson & Phelps, 1966). Accordingly, a large fall in the price of machines or an exogenous boost to technological growth (Katz & Autor, 1999) led to increased relative demand for skilled labor. However, as Acemoglu

[6]Further alternative perspectives are offered in Matsuyama (2007) and Feenstra & Hanson (1997).

(2002b) and Berman & Machin (2000) argue, there has not been enough TFP or capital deepening to account for the skill-bias generated, and these can only be part of the explanation.[7]

An alternative response is that technological change is not always skill-biased and can favor one factor over another, depending on market incentives. This was proposed by Hicks (1963) and by historians Schmookler (1966) and Habbakuk (1962). In modern endogenous growth models, the development of technologies follows a profit motive and it naturally follows that the choice to research or implement a technology that improves the productivity of skilled workers – as opposed to the productivity of unskilled workers – depends on the relative profitability of the two technologies. There are many examples from history in which technological change favored unskilled workers in developed countries (Rosenberg, 1969; Hayami & Ruttan, 1970; Mokyr, 1990) and this study will shortly discuss examples from developing countries.

Determinants of the Skill Bias of Technology

From the perspective of a developing country, the acquisition of technologies favoring skilled workers as opposed to technologies that favor unskilled workers depends on the relative cost of the two types of technology and the relative revenues they generate. Relative costs are based on the relative availability of skill-biased technologies, which in turn is based on the skill-bias of R&D in developed countries. Skill-biased machines yield more revenues if there are more skilled people available to use them and if the relative price of skill-intensive goods is higher.

Most countries do not develop their own technologies but acquire them from abroad (Eaton & Kortum, 2001). The top five country sources of patents account for 84 percent of those worldwide but developing countries account for only 3 percent (Behar, 2011). Savvides & Zachariadis (2005) find empirically that developing countries do not undertake their own R&D but rely on foreign technology transfer. According to Eaton & Kortum (2001), those countries engaged in designing the machines tend to produce and export them. This implies that the skill-bias of R&D in the developed world would affect the skill-bias in the developing world.

However, countries do not absorb new methods automatically; they consider domestic factor markets before choosing appropriate technologies. For example, Knight (1979) notes that capital can replace skilled or unskilled labor, and describes how the introduction of the color bar restricted the supply of skills in South Africa and may have led to capital substituting for skilled workers. When the color bar was relaxed, a large degree of substitution of machines

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[7] In South Africa, for example, accelerated SBTC was observed despite a fall in the pace of investment in physical capital (Fedderke et al, 2001).

for *unskilled* labor took place. Fransman (1985) presents case study evidence of developing countries adapting overseas technologies to local conditions. Esposito & Stehrer (2009) find econometric evidence consistent with a positive relationship between the initial relative quantity of skilled labor and subsequent SBTC.

International trade can also affect technological change through a number of mechanisms.[8] Our emphasis here is on how this can affect the skill-bias in developing countries. We have noted that technology is often embodied in machines. It follows that trade liberalization would decrease the cost of those machines (Krusell et al., 2000; Burnstein et al., 2012). For this to be a mechanism for openness to lead to SBTC, as proposed in the skill-enhancing trade hypothesis (Robbins, 1996, 2003), opening up needs to lead to a change in the relative access to skill-biased technologies as opposed to all technologies. Furthermore, differential impacts in wages across developing countries would need to rely on differential capacity in absorbing technologies (Meschi & Vivarelli, 1999).

Caselli & Wilson (2004) document that technology is embodied in imported machines, but also find evidence that the skill-bias of machines imported varies according to local conditions including human capital. Similarly, Acemoglu & Zilibotti (2001) speak of multinational corporations making technologies available to their various developing country subsidiaries according to the relative availability of skilled workers. Moreover, they cite an example of Kenya using the hammer mill to grind maize rather than the roller mill because of abundant unskilled labor. This is consistent with the previous discussion on appropriate technologies but also consistent with globalization leading to different degrees of skill bias depending on local conditions.

Almeida (2009) finds evidence that increased openness in Asia led to SBTC in the MICs but not the LICs, offering the prevailing plausible interpretation that this is because LICs do not have the capacity to absorb new technologies. However, it is also legitimate to explain the difference using factor abundance. Endowments affect the pattern of specialization after trade such that MICs are expected to export relatively skill-saving goods to advanced countries and relatively skill-intensive goods to other developing countries. Supporting evidence comes from Gourdon (2011), who finds that technological change in developing countries was more skill-biased in sectors engaged in South-South trade than in South-North trade. Therefore, while trade with advanced countries may grant more access to technology than trade with other developing countries (Meschi & Vivarelli, 2009), there is also evidence that the degree of skill-bias is driven by HOSS patterns.

Advanced countries direct their R&D efforts according to local conditions, which implies that there was SBTC induced by trade and by skill supply (Chusseau et al, 2008; Kiley, 1999; Acemoglu, 1998), which partly explains why technical change has been skill-biased in

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[8] See for example Wood (1994), Thoenig & Verdier (2003), and Bustos (2011).

advanced countries. Putting this advanced country SBTC together with the tendency for developing countries to import foreign technologies, the implication is that technology adoption in developing countries is influenced by that in advanced countries. As argued by Berman & Machin (2000:3), *"...developing countries must be choosing from a menu of best practices that includes an ever-increasing proportion of skill-biased technologies."* Further support comes from Berman, Bound & Machin (1998), who find evidence for pervasive global SBTC and that the same industries experiencing SBTC in the developing countries in the 1980s were those experiencing it in the developed countries in prior decades. However, developing countries do not absorb technology by osmosis and, as we have argued, the skill-bias depends on developing country characteristics, including their endowments. A higher skill endowment induces SBTC, which may be why there is no correlation between the quantity of skills and inequality. Recent trade liberalization may have raised the profitability of skill-biased technologies in skill-abundant developing countries and had the opposite effect in skill-scarce developing countries.

III. THEORY

This section sets up the model. The core components are skilled and unskilled intermediates, which are used to make a homogenous final good. Skilled intermediates are produced by intermediates producers, who employ skilled labor using numerous varieties of machines. Unskilled intermediates are made analogously with unskilled workers and different varieties of machines. The relative wages of skilled and unskilled workers are a function of their relative physical productivity, which depends on how many machine varieties they have, and on the relative prices of skilled and unskilled intermediates, which may either depend on their relative supply or on the exogenous global price ratio.

The relative availability of machines is determined in the technology market, and depends on the decisions of prospective technology licence holders. Prospective licence holders base their decisions on the costs of those licences, which are a function of global R&D, and on the potential revenues derived from those licences, which are a function of the quantity of skilled labor relative to unskilled labor and of the price of skilled intermediates relative to unskilled intermediates.

Equilibrium in the technology market requires that the relative cost of acquiring a skill-biased technology be equal to the relative value of that technology. By bringing together numerous drivers of SBTC, the presentation in this section attempts to economize on notation, derivation and qualifications of conditions for legitimate equilibria. More details are available on request.

A. Production

Total output of final goods is a CES aggregate of two types of intermediate, as described by the linearly homogeneous technology:

$$Y_t = \left[(y_t^s)^{\frac{\epsilon-1}{\epsilon}} + (y_t^u)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \tag{1}$$

Final output is produced by perfect competitors using two intermediate inputs purchased from intermediates producers. The price of final output is unity. $\epsilon > 0$ is the finite elasticity of substitution between intermediate inputs. Individual producers take the price of final output and intermediate input prices as given before choosing their optimal quantities of intermediates.

This study employs a variety expansion model (Romer, 1990). As in Kiley (1999), intermediates are produced by i perfectly competitive firms, where y^s uses skilled labor L^s and T^s different machines while y^u uses unskilled labor L^u and T^u different machines. Specifically, $y_{it}^s = (L_{it}^s)^{1-\alpha} \sum_{j=1}^{T_t^s} X_{ijt}^{\alpha}$ and $y_{it}^u = (L_{it}^u)^{1-\alpha} \sum_{j=1}^{T_t^u} Z_{ijt}^{\alpha}$. X_{ijt} is machine input of type j used by firm i at t. It is the quantity of each of T^s machines (capital) that complement skilled labor. Similarly, Z_{ijt} is the quantity of each of T^u machines complementing unskilled labor.

The price of final output is unity. Firms are profit maximizers and the quantity of each skilled machine demanded by each intermediates producer is such that the marginal product of the machine equals its price. Firm-level demand for each type of skilled machine is $X_{ijt} = \left(\alpha \frac{p_t^s}{p_{jt}^X} \right)^{\frac{1}{1-\alpha}} L_{it}^s$.

The price of each skilled machine, p_{jt}^X, is set by the firm holding the licence for that type of machine. The technology importer must receive ex post profits sufficient to cover the ex ante licence cost. We describe technology acquisition below but, once the fixed cost of acquiring the licence has been incurred, it costs 1 unit of Y, which has a price of 1, to import each machine. The equation for firm-level demand can be used to show the own-price elasticity of demand is $\frac{1}{1-\alpha}$ for all machines of any type. Therefore, each monopolist sets a profit maximizing price of $\frac{1}{\alpha}$ for all j, t. For the economy as a whole, we can condition demand for skilled machines on the quantity of skilled labor. Because final goods are produced using a constant returns to scale technology, equilibrium economy-wide demand for each skill-biased intermediate j must be:

$$X_t = \alpha^{\frac{2}{1-\alpha}} (p_t^s)^{\frac{1}{1-\alpha}} L_t^s \tag{2}$$

Similarly, economy-wide demand for each unskilled machine is:

$$Z_t = A\alpha^{\frac{2}{1-\alpha}} \left(p_t^u\right)^{\frac{1}{1-\alpha}} L_t^u \tag{3}$$

Economy-wide output of skilled and unskilled intermediates is:

$$y_t^s = T_t^s \left(L_t^s\right)^{1-\alpha} X_t^\alpha \tag{4a}$$
$$y_t^u = T_t^u \left(L_t^u\right)^{1-\alpha} Z_t^\alpha \tag{4b}$$

There are constant returns to increases in the variety of inputs; as long as T^s or T^u rise, y^s or y^u will rise. The model literally considers T^s and T^u as the number of different types of machines a firm can use, but can also be thought of as the technical complexity of the firms' production processes (Barro & Sala-i-Martin, 2004).

B. Prices and Wages

Each final output producer l chooses its ratio of intermediates such that:

$$\frac{y_{lt}^s}{y_{lt}^u} = \left(\frac{p_t^s}{p_t^u}\right)^{-\epsilon} \tag{5}$$

In a closed economy, demand equals supply of each intermediate input. For the economy to be in equilibrium, intermediates must have prices p^s and p^u such that.

$$\frac{p_t^s}{p_t^u} = \left(\frac{y_t^s}{y_t^u}\right)^{-\frac{1}{\epsilon}} \tag{6}$$

For a closed economy, a rise in supply of one of the inputs relative to the other would necessitate a relative price adjustment. After substituting from (2) and (3), combining (4) and (6), we can write

$$p_t \equiv \left(\frac{p_t^s}{p_t^u}\right)^{\frac{1}{1-\alpha}} = \left(\frac{T_t^s L_t^s}{T_t^u L_t^u}\right)^{\frac{-1}{\sigma}} \equiv (TL)_t^{\frac{-1}{\sigma}}\ , \tag{7}$$

where $T \equiv \frac{T^s}{T^u}$, $L \equiv \frac{L^s}{L^u}$ and $\sigma = \epsilon + \alpha - \epsilon\alpha$ is the elasticity of substitution between skilled and unskilled labor. An exogenous change in the relative skill supply would lead to a rise in the relative quantity of y^s produced. If the ratio of T^s to T^u were to change, this too would necessitate an adjustment in the relative price. Equation (7) shows a negative relationship between the relative price of the skill-intensive good on the one hand and the relative number of skilled technologies on the other.

In a small open economy, prices are set internationally. Final goods producers still choose intermediates according to equation (5) but their choice is no longer influenced by domestic production of intermediates. Demand-supply mismatches are met through imports or exports, so that increases in relative supply of skilled intermediates do not require a fall in relative prices to be absorbed by local final goods producers. Consistent with H-O theory, open economies that have high skill supply will tend to export skilled intermediates.[9]

Producers of intermediate goods hire labor such that wage equals marginal revenue product. Therefore, relative wages are a function of the relative price received for skilled and unskilled intermediates and the relative physical productivities of the workers (given by T). Therefore, the ratio of skilled to unskilled wages is:

$$W_t = T_t p_t \tag{8}$$

The next section discusses technology itself as a function of skill supply and prices.

C. Modeling Technology Adoption

Relative wages are a function of the relative availability of skilled and unskilled technologies, which is determined in the technology market.

For a prospective licence-holder of a particular technology, it costs one unit of Y to import one unit of a machine, skilled or unskilled, such that the marginal cost is unity for both machine types. The cost of acquiring a skilled *licence* for a particular skilled machine X_j is C^s and the cost of a licence for an unskilled machine Z_j is C^u units of Y exported. The price of a licence is inversely related to the research frontier reached by R&D in the developed world. The price is also higher if the next available technology is closer to the technology frontier: $C^s = \left(\frac{T^s}{R^s}\right)^k$ and $C^u = \left(\frac{T^u}{R^s}\right)^k, k > 0$. Defining $C \equiv \frac{C^S}{C^u}$,

$$C_t = \left(\frac{T_t}{R_t}\right)^k \tag{9}$$

R is the skill-bias of the world's available technologies such that the relative cost of importing skilled technologies is inversely related to it. k governs how fast the cost of a licence rises as we get closer to the technology frontier.

At any time t, the potential licensee considers if the value of the licence exceeds the cost. The value is the present value of future profits, which is the same for all skilled machine types. Thus the value of a skilled licence at time t is $V_t^s = \sum_i^{\infty} \left(P_{t+i}^X - 1\right) X_{t+i} \left(1+r\right)^{-i}$, where r is an internationally set interest rate. Recalling $P^X = \frac{1}{\alpha}$, using equation (2) and defining

[9] It is for modeling convenience that we make trade in intermediates. One could alternatively replace equation (1) with a utility function in two final goods. Furthermore, it is now well documented that the majority of the world's goods trade is actually in intermediates.

$\Omega \equiv (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$, the per period profit from a licence for a skilled machine can be written as $\pi^x = \Omega \left(p_t^s\right)^{\frac{1}{1-\alpha}} L_t^s$. Similarly, the per-period profit for an unskilled licence is described by $\pi^z = \Omega \left(p_t^u\right)^{\frac{1}{1-\alpha}} L_t^u$. Therefore, the value of a skilled licence is

$$V_t^s = \Omega \left[\sum_{i=1}^{\infty} \frac{L_{t+i}^s \left(p_{t+i}^s\right)^{\frac{1}{1-\alpha}}}{(1+r)^i} \right] \tag{10}$$

and the value of an unskilled licence is

$$V_t^u = \Omega \left[\sum_{i=1}^{\infty} \frac{L_{t+i}^u \left(p_{t+i}^u\right)^{\frac{1}{1-\alpha}}}{(1+r)^i} \right]. \tag{11}$$

For constant values of L and R, an equilibrium can be found in which p, V and T are constant, and time subscripts can be dropped. Under these assumptions, the relative value of a skilled technology $V \equiv \frac{V^s}{V^u}$ is given by

$$V = Lp, \tag{12}$$

which intuitively shows that skilled technologies are more valuable to adopt if there are relatively more skilled people to work with them and if the price received for a skilled intermediate is higher. By free entry, $V^s = C^s$ and $V^u = C^u$, so

$$V = C \tag{13}$$

and

$$T = R\,(Lp)^{1/k} \tag{14}$$

The ratio of skilled to unskilled technologies in developing countries is positively related to the relative availability of skilled technology licences in the world. It is also positively related to the relative price of skilled intermediates and to the relative supply of skilled labor. Equation (14) summarizes the three mechanisms driving the skill-bias of technical change, namely skill-biased R&D in rich countries (increase in R), expanded education access (increase in L, under certain conditions), and international trade (which increases p for a skill-abundant developing country). By equations (8) and (14):

$$W = RL^{1/k} p^{\frac{k+1}{k}} \tag{15}$$

The skill premium is positively related to the relative price of skill intermediates. It is also positively related to the skill supply and skill-bias of the technology frontier, although these two factors can affect p. Specifically, in a closed economy, equation (7) can be used to substitute for p such that

$$T = L^{\frac{\sigma-1}{\sigma k+1}} R^{\frac{\sigma k}{\sigma k+1}}, \tag{16}$$

$$p = R^{\frac{-k}{\sigma k+1}} L^{\frac{-(k+1)}{\sigma k+1}}$$

and

$$W = L^{\frac{\sigma-2-k}{\sigma k+1}} R^{\frac{k(\sigma-1)}{\sigma k+1}} \tag{17}$$

These equations show that the elasticity of substitution between skilled and unskilled labor, σ, is an important parameter governing the sign and extent of the response of wages to skill supply and SBTC in the advanced countries. For R in particular, the response is positive if and only if $\sigma > 1$. These parameters govern how much the relative price of skilled intermediates would have to fall to preserve equilibrium after an increase in the supply of skilled intermediates, which has implications for how much p falls in response to a rise in relative skill supply or skill-biased technologies. The other results, in particular for skill supply and opening up to the economy, hold for any feasible value; that is $\sigma > 0$, but the mechanisms can be different, and there is an empirical consensus that the elasticity lies above 1 (Acdemoglu, 2002a; Behar, 2009; Freeman, 1986). The discussion of comparative statics that follows assumes that $\sigma > 1$.

IV. COMPARATIVE STATICS

A. Skill-biased Technical Change in Advanced Countries

It is straightforward to show that the steady-state ratio of T is unequivocally positively related to the availability of skill-biased technologies researched and developed by advanced countries. In particular, a rise in R leads to a rise in T in both open and closed economies (equations 14 and 16) and regardless of their endowments. In a small open economy, $\frac{d \ln W}{d \ln R} = 1$ but, because the change in R is pervasive, all countries would experience this. Extra availability of skilled intermediates necessitates a fall in the the international relative price of skilled goods. This feedback effect into p and hence W is akin to the closed economy setting:

$$\frac{d \ln W}{d \ln R} = \frac{k(\sigma - 1)}{\sigma k + 1} \tag{18}$$

These simple steady-state comparative static findings echo those in Behar (2011), who models these features in a dynamic multi-period context. Faster R&D in the advanced economies leads to faster growth in developing economies but, reflecting persistent SBTC in the North, R^s grows faster than R^u in all periods such that wage inequality is persistently growing.

These results of course rely on the ability to import machines from abroad. Increasing the availability of technology spurs economic growth. Furthermore, an economy that has been closed for a long period of time may not have had access to recent technologies during a period when R is rising, so that its effective relative cost of skilled machines is much higher than implied by R. Upon opening up to trade, this would be tantamount to a rise in R and would consequently induce SBTC. This mechanism would be similar to the skill-enhancing trade hypothesis due to Robbins (1996; 2003). Differential effects between the skill-abundant and skill-scarce developing countries would rely on additional arguments; for example differences in absorption capacity (Meschi & Vivarelli, 2009), or differential effects of trade liberalization on the incentives to acquire skill-biased technologies, as discussed next.

B. Trade, Skill Supply and the Skill Premium (Small Open Economy)

The SOE is a developing country but is skill-abundant, as discussed earlier; it is straightforward to develop analogues for LICs or other skill-scarce country groups. In particular, the SOE has $L > L'$, where L' is the world ratio of skilled to unskilled labor. All other characteristics – including the relative access to skilled and unskilled technologies, $R = R'$, and the production technology – are the same. In the rest of the world, $T' = L'^{\frac{\sigma-1}{\sigma k+1}} R^{\frac{\sigma k}{\sigma k+1}} < T$ for $\sigma > 1$, $p' = R^{\frac{-k}{\sigma k+1}} L'^{\frac{-(k+1)}{\sigma k+1}} > p$ and $W' = L'^{\frac{\sigma-2-k}{\sigma k+1}} R^{\frac{k(\sigma-1)}{\sigma k+1}}$.

After opening up the intermediates goods market to trade, the SOE now faces the world price p'. With no technical change, one can show that the skill premium rises in accordance with the standard HOSS effect, i.e.:

$$\frac{W_{HOSS}}{W_{closed}} = \frac{p'}{p} = \left(\frac{L'}{L}\right)^{\frac{-(k+1)}{\sigma k+1}} > 1 \tag{19}$$

However, allowing for endogenous skill-biased technical change, T rises in response to the higher relative prices. As a result, there is a further increase in the wage premium such that, using (14)

$$\frac{W_{SOE}}{W_{closed}} = \left(\frac{p'}{p}\right)^{\frac{k+1}{k}} = \left(\frac{L'}{L}\right)^{\frac{-(k+1)}{\sigma k+1}\frac{k+1}{k}} > \frac{W_{HOSS}}{W_{closed}} \tag{20}$$

The $\frac{k+1}{k} > 1$ superscript on the relative price terms shows that the change in relative prices increases the returns to factors in a standard HOSS sense but also the relative productivity of factors through the endogenous SBTC. The endogenous price differential is ultimately a function of the asymmetry in skill endowment, and the additional superscript on the relative endowment can be interpreted as an amplification of the effective relative skill endowment brought about by endogenous SBTC. The magnitude of the SBTC is a function of how quickly the cost of a licence rises as technologies are acquired (k). By equation (5), the rise in relative prices from p to p' leads to net exports of skilled intermediates by the skill-abundant developing country. Furthermore, the rise in T leads to a further increase in the relative supply (cf. equations (4)) and, hence, net exports of skilled intermediates.

In Acemoglu (2003), the opening up to trade in advanced economies leads to SBTC in those countries, which then translates to SBTC in less developed countries even if the relative price of skilled goods falls in the less developed countries. Here, skill-abundant developing countries experience technical change that favors skilled workers because the relative price of skilled goods is rising in these countries. Importantly, an analogous treatment for a skill-scarce SOE would indicate a fall in the relative price of skilled intermediates and the adoption of technologies that favor unskilled workers. The skill-scarce SOE would also be a net importer of skilled intermediates.

We have assumed that the country had access to R before opening up to trade in intermediates. It is clearly unrealistic to assume a country would have the same access to the technology frontier. As already discussed, it is also plausible that the ratio R would exceed the ratio of available technologies in the closed developing economy. If so, trade liberalization would coincide with a rise in R and hence further SBTC.

Further, note that $W_{SOE} = RL^{1/k}p'^{\frac{k+1}{k}}$ (cf equation 15) and that, because the SOE is a price taker

$$\frac{d\ln W}{d\ln L} = \frac{1}{k}, \tag{21}$$

which is unequivocally positive. The mechanism is that increased relative availability of skills makes the value of skill-biased technologies relatively high, which leads to SBTC and hence increases the relative wage of skilled labor. The extent of SBTC depends on how quickly licence prices rise (k).

C. Trade, Skill Supply and the Skill Premium (Medium Economy)

The results in the previous section are strong and clear because of the absence of feedback effects from the SOE onto prices. In a closed economy, a rise in skill supply can induce a standard substitution effect – more skilled labor relative to unskilled labor induces a fall in the skill premium – ceteris paribus. The substitution effect operates via the effect of skill supply on the relative quantity of skilled intermediates and hence the relative price of intermediates. Similarly, SBTC affects the relative quantity and price of skilled intermediates. Therefore, the effect of skill supply or trade on the skill premium becomes a function of the elasticity of substitution (Acemoglu 2002b, Behar, 2009).

To allow for the possibility of feedback effects and qualify the results, the case of two large symmetric developing countries opening up to trade can be interpreted as a multilateral trade liberalization involving two groups of countries. As before, $L' < L$. In this setting, the world price will be a function of the endowments and technologies in both countries:

$$p_{medium} = \left(\frac{T^s L^s + T'^s L'^s}{T^u L^u + T'^u L'^u} \right)^{\frac{-1}{\sigma}} \tag{22}$$

We know $T = R\left(L p_{medium}\right)^{1/k}$ and, analogously, $T' = R\left(L' p_{medium}\right)^{1/k}$ so that $T'/T = (L'/L)^{1/k}$. Therefore, $T'^s = T^s \left(\frac{L'^s}{L^s}\right)^{1/k}$ and $T'^u = T^u \left(\frac{L'^u}{L^u}\right)^{1/k}$. Letting $\lambda \equiv \frac{1+\left(\frac{L'^s}{L^s}\right)^{\frac{k+1}{k}}}{1+\left(\frac{L'^u}{L^u}\right)^{\frac{k+1}{k}}}$ denote the degree of asymmetry in skill abundance between the two countries, the equilibrium world price of goods can be rewritten as $p_{medium} = (TL\lambda)^{\frac{-1}{\sigma}}$. The assumption that $L' < L$ implies $\lambda < 1$. The technology ratio in the middle income skill-abundant country (with analogues for the low income countries) is $T = L^{\frac{\sigma-1}{\sigma k+1}} R^{\frac{\sigma k}{\sigma k+1}} \lambda^{\frac{-1}{\sigma k+1}}$, and $p_{medium} = R^{\frac{-k}{\sigma k+1}} L^{\frac{-(k+1)}{\sigma k+1}} \lambda^{\frac{-k}{\sigma k+1}}$ so that wages are given by $W_{medium} = L^{\frac{\sigma-k-2}{\sigma k+1}} R^{\frac{k(\sigma-1)}{\sigma k+1}} \lambda^{\frac{-(k+1)}{\sigma k+1}}$

$$\frac{W_{medium}}{W_{closed}} = \lambda^{\frac{-(k+1)}{\sigma k+1}} \tag{23}$$

It is straightforward to confirm that $W_{medium} > W_{closed}$ and that the differential is bigger than in the absence of induced SBTC, although the differential is not as large as in the SOE case because of feedback effects to relative prices. This amplification effect is important because quantified HOSS effects tend to fall far short of the observed wage changes (Chusseau et al, 2008). Furthermore, it can attend to two shortcomings of the HOSS model (Kurokawa, 2014). First, the price feedback effect can explain why there are sometimes big wage changes without the commensurate changes in product prices. Second, SBTC explains the empirical observation that relative wages are not equalized across all countries.

As before, steady state changes in R increase the skill premium. Furthermore, the response of wages to increased skill supply is given by:

$$\frac{d \ln W}{d \ln L} = \frac{\sigma - 2 - k}{\sigma k + 1} - \frac{k+1}{\sigma k + 1} \frac{\partial \ln \lambda}{\partial \ln L} \tag{24}$$

In the case where all/both countries simultaneously increase their skill supply, then λ is unchanged and the last term drops out. This case is analytically the same as a closed economy, which has been analyzed by Acemoglu (2002) and Behar (2009). In a closed economy, as before, the mechanism is that increased relative availability of skills makes the value of skill-biased technologies relatively high, which tends to increase the relative wage of skilled labor, and this effect is mitigated by the increasing licence cost. However, the SBTC effect is countered by the standard substitution effect (where an increase in relative skill supply reduces the wage premium in the absence of technical change). Specifically, the increased relative supply of skills and skilled machines brings about an increased supply of skilled intermediates, a fall in the relative price of skilled intermediates and hence a fall in the relative marginal revenue product of skilled labor. The size of these mitigating effects through prices is governed by $\sigma = \epsilon + \alpha - \epsilon\alpha$: a higher value of σ means that only small changes in relative prices and wages are needed to restore equilibrium in the intermediates and labor markets. If skilled and unskilled labor are perfect substitutes ($\sigma \longrightarrow \infty$), $\frac{d \ln W}{d \ln L} = 1/k$ in a closed economy, which echoes the SOE setting above. More generally, the derivative is positive for a value of σ that is sufficiently high. In a closed economy, this is specifically $\sigma > k + 2$ or at least 2.

Turning to the case where only the MIC increases its skill supply; that is, L rises but L' does not; it is straightforward to show that $\frac{\partial \ln \lambda}{\partial \ln L} < 0$, reflecting an increase in the endowment asymmetry between countries. In terms of equation (24), the elasticity threshold for a positive derivative is lower than $k + 2$ but the extent is highly dependent on the relative factor endowments (λ) and k. It would also be dependent on the relative sizes of the economies, which have been assumed equal for convenience but not realism.

For developing countries[10] using macroeconomic data, Psacharopoulos & Hinchliffe (1972) estimate σ to be 2.1 to 2.5 but also generate elasticities as high as 1000 and more modern studies are hard to find. Microeconomic studies tend to generate lower elasticities but these are also extremely rare for developing countries. It's also of course impractical to try to estimate k. However, recall that there appears to be little or no correlation between relative skill supply and the wage premium. This would imply that the endogenous skill-biased technical change effect is countered by the standard substitution effect. In this context, SBTC offers an explanation for why skill supply does not necessarily reduce the wage premium.

V. CONCLUSION

Skill-biased technical change (SBTC) is an important contributor to the higher inequality observed in developing countries. This paper has presented the case that technical change in developing countries is not necessarily skill-biased, but has been because of the increasing availability of skill-biased technologies researched and developed by advanced economies. This study has argued that opening up to international trade affects the relative prices of skill-intensive goods, which affects the skill-bias of technology adoption. MICs tend to be

[10] Acemoglu (1998) argues that σ is sufficiently large for the directed technical change effect to outweigh the substitution effect in the United States and other advanced countries, and that this explains the simultaneous increase in educational attainment and wage premia. Freeman (1986) offers a consensus estimate of between 1 and 2 for developed countries but some estimates are substantially higher.

skill-abundant relative to the rest of the world, so trade liberalization would increase the relative price of skill-intensive goods and make the adoption of skill-biased technologies more attractive. The opposite is true for skill-scarce developing countries. The skill bias is also determined by the endowment of skilled labor, which is why an increase in the supply of skilled labor stimulates SBTC such that skill supply creates its own demand. SBTC helps address critiques of trade-based explanations of higher inequality by endogenously amplifying the Heckscher Ohlin Stolper Samuelson (HOSS) effects of trade liberalization.

These phenomena help explain pervasive increasing wage inequality within developing countries because the technologies available to developing countries increasingly favor skilled workers even if these countries are skill-scarce. The failure of increased educational attainment to reduce wage inequality is attributed to induced SBTC acting against the standard substitution effect. Trade-induced SBTC helps explain the negative correlation between trade and inequality in LICs and the zero or positive correlation in MICs.

While access to foreign technology, an increase in human capital and trade openness are important ingredients for productivity gains and economic growth, they may not reduce inequality, especially in MICs. To ensure that all benefit from growth, appropriate policies may be needed to protect the vulnerable and to distribute the proceeds of such productivity gains. Equipping people with skills is a reasonable response to the SBTC brought about by globalization. However, in the race between education and technology (Tinbergen, 1975), recipients of expanded education may be able to adapt to SBTC, but this may not reduce inequality and would not help those who remain unskilled.

APPENDIX

Data and Methodological Description

The inequality data used in three of the linear projections in Table 1 is the EHII, which is an index from 0-100 of household income inequality from 1963 to 2003. More information on the data, which is also used in Table 2 and is constructed by the University of Texas Inequality Project (UTIP), is available at http://utip.gov.utexas.edu/data.html. International trade data is taken from the IMF *World Economic Outlook* database (October 2012 version), based on the Direction of Trade Statistics, which is also used in Table 4. Both of these are available annually but we take five-year averages to match the educational attainment data for 1980, 1985, 1990, 1995 and 2000 (Barro & Lee, 2001). The proportion of skilled workers is constructed by aggregating those with completed primary school or more schooling using the procedure in Caselli & Coleman (2006). Similarly, the proportion of unskilled workers is constructed by aggregating the levels of attainment below the completion of primary school. Altogether, data is available for about 50 developing countries. These projections include country fixed effects and exploit the within-country variation over time, such that the coefficients can represent the correlations between the extent of increased skill supply, international trade and inequality over time. The positive trend coefficient can be interpreted as pervasive SBTC, and similar results are achieved using individual period dummies. As a robustness check of the first three projections in Table 1 in the body of the paper, Table A1 presents specifications that use alternative measures of trade openness.

Table 1 also presents two linear projections on the skill premium as an alternative to household inequality. The skill premium is the ratio of wages received by skilled relative to unskilled workers. Using the constructed proportions of skilled and unskilled workers, this paper calculates the appropriately weighted skill premium based on Mincerian earnings regression coefficients taken from Behar (2009). As an alternative to the trade-to-GDP ratio, a widely adopted measure of openness is taken from Sachs & Warner (1999).[11] The projections rely on a cross-sectional dataset for 43 developing countries from 1985 onwards. While the data coverage is more limited than for the EHII-based analysis, it offers a closer match to the wage premium in the formal modeling. The estimation method is Ordinary Least Squares with robust standard errors, but estimation based on Least Absolute Deviations yields similar results. More details on the methodology are available in Behar (2009).

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[11] A country is not open if (i) average tariffs exceed 40 percent; (ii) nontariff barriers cover more than 40 percent of imports; (iii) it has a socialist economic system; (iv) the black market premium on the exchange rate exceeds 20 percent; or (v) exports are controlled by a state monopoly.

Table A1: Additional Projections of Inequality on Education, Trade and Time for Developing Countries

Dependent Variable:[1]		EHII			EHII			EHII	
Countries:	LIC	LMIC	UMIC	LIC	LMIC	UMIC	LIC	LMIC	UMIC
Skilled Proportion	-0.179*	0.0602	-0.0634	-0.236*	0.0574	-0.0564	-0.221*	0.0557	-0.0604
Standard error	[0.0971]	[0.0709]	[0.0959]	[0.119]	[0.0762]	[0.0899]	[0.107]	[0.0769]	[0.0937]
Trend	0.12	0.210***	0.327**	0.139	0.213***	0.337**	0.179**	0.212***	0.328**
Standard error	[0.106]	[0.0714]	[0.132]	[0.086]	[0.067]	[0.137]	[0.0788]	[0.0695]	[0.13]
Trade/GDP share (Goods, Services)	-4.619**	0.0783	2.15						
Standard error	[1.987]	[1.2]	[3.968]						
Export/GDP share (Goods)							-5.905*	0.39	1.172
Standard error							[2.84]	[1.673]	[2.906]
Export/GDP share (Goods, Services)				-5.686*	0.279	0.727			
Standard error				[2.71]	[1.45]	[1.91]			
Constant	-171	-375.2**	-614.3**	-211.5	-381.1***	-629.2**	-288.9*	-379.6**	-612.9**
Standard error	[213.8]	[140]	[264.4]	[177.6]	[132.2]	[270.7]	[163.3]	[136.6]	[256.5]
R^2	0.15	0.27	0.25	0.22	0.27	0.24	0.18	0.27	0.24
N	38	62	60	38	62	60	38	62	60
Countries	15	20	15	15	20	15	15	20	15

[1] EHII is index of household income inequality and projected on the log of the proportion of the population who have completed at least primary school, the log of trade openness, and a five-year trend term using country fixed effects in a panel. The three alternative measures of trade openness are the ratio of goods and services trade to GDP, the ratio of goods exports to GDP, and the ratio of goods and services exports to GDP. Projections are for Upper-Middle-Income (UMIC), Lower-Middle-Income (LIMIC) and Low-Income (LIC) countries. *, ** and *** denote significance at 10%, 5% and 1% based on robust standard errors in brackets.

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