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Economic transformation, population growth and the long-run world income distribution☆

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ABSTRACT

We present and calibrate a model where trade with advanced economies spurs development, and trade opportunities depend on the relative population in advanced and developing countries. As developing countries become advanced, prospects improve for the remaining developing countries. If population growth differentials between developing and advanced economies are small, economic development accelerates over time. Otherwise, long-run global prosperity requires a sufficiently large initial population in advanced countries. More open countries develop faster, but more openness by all developing countries may only modestly increase their aggregate growth. China's development may hurt developing countries in the short-run, but improves their long-run prospects.

1. Introduction

Integration with the world economy has arguably been the chief route from poverty to wealth. Japan exported cheap goods after World War II and later moved on to more technologically sophisticated products. As Japan grew, Korea, Taiwan Province of China, Hong Kong SAR and Singapore replaced Japan as low wage exporters, and when these economies moved on to more sophisticated products, Thailand and Malaysia filled their niche. More recently, China has become an important exporter of manufactured goods and India is increasingly moving into services exports. A number of explanations have been advanced for the link between non-traditional exports and growth, including learning and political economy effects of trade. This paper does not seek to model the reasons for this link, but instead, takes it as given and explores its implications for the long-run evolution of the world income distribution.

We present a model in which countries have an opportunity to develop when they integrate with the world economy by producing non-traditional exports for advanced countries. A developing country's export opportunities are greater the more potential buyers there are in advanced countries and the fewer potential competitors there are in developing countries. Thus, as developing countries succeed in becoming advanced economies, their success will improve the export opportunities for the remaining developing countries, which can lead to accelerating global growth. Once China, for example, becomes rich, a billion more people will live in a country that imports labor-intensive goods and a billion fewer in a country that exports them, opening up opportunities for other countries to fill this niche. Whether the world economy converges to a state of widespread prosperity depends on the extent of barriers to trade, the rate at which developing countries that are engaging in trade become advanced economies, migration rates, population growth rates in rich and poor countries, and potentially on initial conditions. A key factor influencing the long-run evaluation of the world economy is differences in population growth rates between countries. If the disparity in population growth rates between developing and advanced countries is not large relative to the economic transformation and migration rates, then the proportion of the world population living in advanced countries will increase indefinitely. If the disparity in population growth rates is sufficiently large, then the long-term evolution of the world economy will depend on whether or not the share of the population living in advanced countries (and resulting demand for developing country labor and migration) is above a critical level necessary for the development and migration process to dominate the opposing demographic trend. If it is above (below) that critical level,

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the proportion of the world population living in advanced (developing) countries increases indefinitely.

A simple decomposition of trends in world population shows that in the 19th century, the proportion of the world population living in advanced economies grew despite a slow rate at which developing countries transformed into advanced economies because population growth in advanced countries exceeded that in poor countries. In the 20th century advances in cheap easy-to-use medical technology, such as vaccines and antibiotics, disproportionately reduced mortality in the developing world and this, combined with falling fertility in the advanced world, led to rapid declines in the share of the world population in advanced countries. Calibration based on the post-war period suggests disparities in population growth rates are large enough that the proportion of the world population living in poor countries will not decline rapidly. In fact, in our baseline calibration, the proportion of the world population in advanced countries is currently below the critical threshold for the world economy to converge to the favorable steady state. However, if population growth in the developing world continues to decline faster than in advanced countries (as projected by the United Nations), the system will converge to the favorable steady state, albeit extremely slowly. An increase in the rate at which poor countries develop disproportionately increases the speed of convergence, due to the model's non-linearities. Rapid growth in China and India would translate into a large increase in the proportion of the world population in advanced economies, moving that ratio well above its critical threshold. That would lead to an acceleration of development elsewhere and a rapid convergence to widespread prosperity (that is, a convergence that takes decades not centuries).

The model also suggests that improvements in policy that reduce the cost of trade can lead to rapid growth for a particular country, but that the response of world growth to a similar improvement by all developing countries will be much smaller. In our model, a developing country will only start exporting to advanced economies once all the other developing countries with lower costs have already done so. When a country improves its policy environment by reducing tariffs or other barriers to trade, it advances its place in the "queue" of countries waiting to integrate into the world economy. But given the limited capacity to absorb all the labor in the developing world, the speed at which development occurs is itself constrained by the size of advanced economies (and small improvements in the average trade cost will only translate into small gains in global growth). This queuing feature might help explain why growth failed to pick up in many developing countries despite policy improvements in the past decades (for example, much progress has been made in trade liberalization and macroeconomic stability). Under the model, even if some developing countries have policies that are so bad that they would never integrate into the global economy, the world may still converge to a widespread prosperity steady-state since labor from these "hopeless" countries could be absorbed into the global economy through migration, as long as there are not too many of these countries.

Our paper is related to previous studies that analyzed economic growth in the (very) long-run. Quah (1993) and Kremer et al. (2001) consider a transition matrix analysis of the world income distribution. Our model departs from the transition matrix approach in allowing transition probabilities to depend on the state of the world economy. This can generate more optimistic predictions of accelerating growth in the world economy, with developing countries potentially doing better in the future than countries with similar characteristics have done in the past.

The idea that learning externalities from advanced countries can facilitate the development of poorer countries dates back at least to Gerschenkron (1962). Tamura (1996) presents a model with endogenous choice between fertility and human capital investment, which addresses some of the same issues studied in this paper, showing that as rich countries grow they raise the return on human capital, causing human capital investment, demographic transition, and growth in poor countries. Much of the novelty of our approach relies on focusing on trade as the conduit for transformation and the limitations on the extent to which the modern global economy can absorb all the labor in the developing world. Our analysis also sheds new light on a host of topical issues which likely depend on the relative population in advanced and developing countries, such as the role of migration, the impact of reforms, aid, and the broader implications of the emergence of China.

Perhaps the most closely related model to ours is that of Lucas (2000), in which economic growth begins in a stagnant economy with an exogenous probability, and is then proportional to the difference between a country's income and that of the leading country (which grows at a constant rate).[1] By allowing for an endogenous take-off process and differential population growth, our model can generate much richer dynamics, including multiple steady states. Depending on parameter values and initial conditions, there may be accelerating global growth or a declining fraction of the world population living in rich countries. In that latter scenario, a non-infinitesimal share of developing countries will never be integrated into the global economy and will remain stagnant forever, which would not occur in Lucas (2000), even if his setting was extended to allow for population growth differentials. Our endogenous take-off process also provides a framework for analyzing the impact of channels which depend on the relative size of the rich population in the world, as described above.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 solves for the evolution of global economy. Section 4 introduces differences across countries. Section 5 extends the model to capture terms of trade changes as the global economy develops. Section 6 calibrates the model, and Section 7 concludes.

2. The model

Suppose there are two types of countries: advanced and developing. The world economy consists of a continuum of countries with measure one, and countries are similar to other countries of the same type. We later discuss the effects large countries can have on the evolution of the world economy (which is illustrated in Section 6). Section 4 introduces differences in the barriers to trade across developing countries.

2.1. Production

There are two production technologies: traditional and modern. Labor is the only input and is inelastically supplied. Advanced and developing countries are equally productive in the traditional technology, with each unit of labor producing one unit of the final consumption good. The modern technology includes two tasks: a simple and a complex one. The complex task produces intermediate input H, while the simple task produces intermediate input L. Trade in intermediate inputs potentially allows modern production to be split among countries. The population of advanced countries consists of high-skill workers, and only those countries can produce intermediate good H. The population of developing countries consists of low-skill workers. This polarization of skills is derived as the outcome of an optimal fertility and education investment decision in Section 2.2.

Both types of workers can produce the intermediate good L, which can be produced anywhere, but production in a developing country c

[1] Lucas (2009) presents a model building on that insight where the stock of knowledge in a poor country is a function of its human capital and that of the leading economy, which allows for higher growth during its catching-up process. The model is calibrated using measures of openness, development, and employment share of agriculture to determine the group of countries where this catching-up process has started.

involves an additional cost of δ_c units of the final good. This transaction cost can encompass a number of aspects, such as transport costs (for both the good delivered and for the good received as payment), infrastructure problems, as well as policy-related costs such as tariffs, taxation, enforcement of property-rights and the regulatory environment. We initially consider the case where differences in transaction cost between different developing countries are infinitesimal. That is, $\delta_c \approx \delta \forall c$. Thus:

$$\begin{aligned} Y_{\text{traditional}} &= n_{\text{traditional},c} \\ Y_{\text{modern}} &= AH^{\alpha}L^{1-\alpha} \\ H &= \begin{cases} n_{H,c} \text{ if } c \in \text{advanced} \\ 0 \text{ if } c \in \text{developing} \end{cases} \\ L &= n_{L,c} \text{ if } c \in (\text{advanced}, \text{developing}) \end{aligned}$$

where $0<\alpha<1$, $n_{\text{traditional},c}$, $n_{H,c}$ and $n_{L,c}$ are the number of workers in country c engaged in the traditional production and the production of intermediate goods H and L, respectively. The cost of producing either H or L in an advanced country c is the wage w_{A} in advanced countries, whereas the cost of producing L in a developing country is the wage w_{D} in developing countries plus the transaction cost δ. We assume $A>2(1+\delta)$ so it is inefficient for workers in advanced countries to work in the traditional sector or to produce L as long as there are workers in developing countries in the traditional sector.[2]

2.2. Mortality, fertility, and education

We consider a simple model of fertility choice, drawing on Galor and Mountford (2006). Suppose workers live for two periods. When they are young they only consume part of their parent's time endowment. The level of that consumption will determine their type once adult. When adult, they derive utility from consumption of the final good and from the future income their children will attain. Their utility is:

$$U = \phi \log(Consumption) + (1-\phi)\log\left(\gamma_H w_{c,H} + \gamma_L w_{c,L}\right)$$

where *Consumption* is the consumption of the final good, γ_H and γ_L are the number of high- and low-skill children, which for simplicity (and unrealistically) is assumed to be a continuous variable, and $w_{c,H}$ and $w_{c,L}$ are the wages of workers in the H and L sectors in country c. The amount of time a parent of skill-level j needs to spend in order to produce a children of skill-level k is t_{jk}. Under the preferences above, workers will spend a share ϕ of their time working in order to buy the final consumption good, and the remaining $1-\phi$ raising and educating their children. We assume that for each child borne from a type j parent in a type i country, $\mu_{i,j}$ will die before becoming adults, but after the investment in raising them has been made. Given the substitutability between high- and low-skill children, workers will choose a corner solution for the type of their children unless $w_{c,H}/w_{c,L}=t_{jH}/t_{jL}$.[3]

We assume both H and L parents are equally productive in the production of L-type children ($t_{HL}=t_{LL}$). Producing an H-type children is more costly for both types of parents, but it takes more time for an L-type parent to produce an H-type parent children than it would take for an H-type parent ($t_{HL}<t_{HH}<t_{LH}$). Provided:

$$t_{HH} / t_{HL} < w_{\mathrm{A},H} / w_{\mathrm{A},L} \tag{1}$$

$$t_{LH} / t_{LL} > w_{\mathrm{D},H} / w_{\mathrm{D},L} \tag{2}$$

we will be at a corner solution where people only have high-skill children in advanced countries, and only have low-skill children in developing ones. We assume the parameters are such that these two inequalities hold. One way of ensuring this result is to assume that H cannot be produced in developing countries regardless of the skill-level of the workers, for example due to institutional constraints. We assume that to be the case. Since parents in both countries spend $(1-\phi)$ of their time raising children, the number γ_{D} and γ_{A} of surviving children from a parent in developing and advanced countries is given by:

$$\begin{aligned} \gamma_{\mathrm{D}} &= \frac{(1-\phi)}{t_{LL}}\left(1-\mu_{\mathrm{D},L}\right) \\ \gamma_{\mathrm{A}} &= \frac{(1-\phi)}{t_{HH}}\left(1-\mu_{\mathrm{A},H}\right) \end{aligned}$$

Since $t_{LL}<t_{HH}$, provided the mortality rates $\mu_{\mathrm{D},L}$ and $\mu_{\mathrm{A},H}$ are sufficiently similar, we have $\gamma_{\mathrm{D}}>\gamma_{\mathrm{A}}$. If on the other hand, mortality was sufficiently lower in advanced countries than in developing countries, population growth would be higher in the former (as was indeed the case in the 19th Century).

In this environment, the gross (natural) population growth rates in a homogeneous country will be given by γ. We assume $\mu_{\mathrm{D},L}$ and $\mu_{\mathrm{A},H}$ are sufficiently similar, so that $\gamma_{\mathrm{D}}>\gamma_{\mathrm{A}}$ and (natural) population growth is higher in developing countries. This has been true since the early 20th century (as shown in Section 6).[4]

We assume that migration takes place from developing to advanced countries. Migration flows are restricted by the advanced countries to a proportion of their population. For simplicity, we assume migration does not affect the investment decisions in education, and that migrants become high-skill upon arrival in an advanced country (which is a reasonable approximation provided migration is relatively small).

2.3. Transformation

As noted in the introduction for the last fifty years, integration with the world economy has been nearly ubiquitous among those countries that have moved from poverty to wealth. A number of studies find cross-country evidence of a link between openness and growth (e.g. Frankel and Romer, 1999). Negative effects of natural resources on growth (e.g. Sachs and Warner, 2001) suggest that benefits stem from integration through modern sectors. A number of channels can generate a link between modern sector exports and economic take off in our model. One potential channel is the learning externalities from exporting firms (Hausmann and Rodrik, 2003). While several case studies do find very large spillovers from exporting firms (for example, Rhee and Belot, 1990), the econometric evidence is more mixed, with several papers finding no evidence of spillovers, perhaps because they are so difficult to quantify and measure (for a comprehensive review of the literature on international technology diffusion, please refer to Keller, 2004). Greenstone et al. (2008) identify large spillovers when comparing U.S. counties that won a bid for a major plant with those that narrowly lost it. A more important channel may be the political economy implications of trade integration for learning and productivity growth, for example by weakening forces that resist the adoption of more efficient technologies, as in Parente and Prescott (1994). The productivity gains stemming from the pressure to survive in competitive international markets can potentially be large, as documented by Galdón-Sánchez and Schmitz (2002) for the iron ore industry. We neither model nor take a position on the specific channels through which non-traditional exports trigger learning and

[2] The output of one unit of advanced country labor optimally divided between the complex and simple task is greater or equal to $A/2$. Thus, $A/2>1$ is a sufficient condition for advanced country workers not to work in the traditional sector. Since $A/2$ is a lower-bound on w_{A}, and the cost of importing L is $1+\delta$, $A/2>1+\delta$ is a sufficient condition for importing L to be cheaper than producing it in an advanced country.

[3] Note that since mortality is given by the parent's and the country's type, it will not affect the quality-quantity trade-off (as both types of children are equally affected).

[4] Note that this model can also explain changes in fertility through changes in the parameters t_{LL} and t_{HH}.

economic transformation. Instead, we take that process as exogenous and focus on its implications for the evolution of the world economy.

We assume that in each period, probability that a developing country becomes advanced is equal to p times the share of its population working in the modern sector. Each country faces an independent realization of this shock. The economic transformation occurs at the country level and is not internalized in the wages. Thus, modern sector workers in developing countries must be paid their opportunity cost in the traditional sector.[5] Once a country becomes an advanced economy it remains one from that point onwards.

It is worth noting that trade could potentially cause developing countries to specialize in sectors with limited learning opportunities, harming their technological progress vis-a-vis its autarky rate (Young, 1991). If specialization in low-skill sectors lowers the skill premia relative to autarky, trade can cause parents in developing countries to choose to have more and less educated children (Galor and Mountford, 2006, 2008), and a larger population in the advanced world contributes to keeping the developing world unskilled. Logically, trade could either speed or slow economic transformation, depending on the particular technologies, involved, and it is possible that effects differ across industries, countries and time periods. Our judgment is that in the post-War period the positive effects of trade have typically dominated the negative ones. When the model is calibrated in Section 6 we do find the countries transitioning were indeed more open. Certainly the rapid rise in global trade has coincided with improving prospects for the developing world as a whole (including major countries such as China and India once they have opened their economies).

If the model were to consider relatively large countries, the realizations of the transformation process in these countries would have substantial implications for the world economy, since they could move sizable shares of the world population from the developing to the advanced group. The larger the size of the countries the more stochastic the evolution of the world economy would become. For simplicity, we assume the world economy consists of a continuum of countries, so that its evolution can be, to a close approximation, described by a smooth and deterministic process.

3. Evolution of the world population

There are potentially two stages in the evolution of the world economy: one in which not all developing countries are integrated into the world economy producing for the modern sector and one in which they are. We first consider the former, where the share of population in advanced countries is sufficiently small so that the entire developing country population cannot work in the modern sector.

3.1. Stage 1: Not all developing countries are integrated into the world economy

In this stage there are three groups of countries: advanced countries, developing countries integrated into the world economy, and unintegrated developing countries. Modern sector firms hire developing country workers until the marginal revenue product equals their wage (one if the outside option is the traditional sector) plus the transaction cost δ. In a competitive equilibrium, advanced countries will only demand L from a developing country once all the developing countries with lower transaction costs have already joined the modern sector. We continue to focus on the case where differences in δ across countries are infinitesimal, and only matter to determine the order in which countries join the modern sector.

The number of workers from developing countries working in the modern sector is:

$$N_{\mathrm{DM}} = (A(1-\alpha)/(1+\delta))^{1/\alpha} N_{\mathrm{A}}, \tag{3}$$

where N_{A} is the population in advanced countries. The wage in advanced countries, determined by the marginal product of their labor, is:

$$w_{\mathrm{A}} = \alpha A^{1/\alpha}((1-\alpha)/(1+\delta))^{\frac{1-\alpha}{\alpha}}. \tag{4}$$

Note that the cost δ affects w_{A} but not w_{D}, since the latter is pinned down by the reservation wage in the traditional sector. However, the cost δ harms the developing population by lowering the demand for L and, as a result, slowing down the transformation process (if a worker in an advanced country were to work in the L sector it would earn $1+\delta$). Also note that even though $w_{\mathrm{D}}=1$, a developing country that is integrated into the world economy is better-off than one that is unintegrated, since the former may become an advanced economy. We assume the relative costs of education are such that Eqs. (1) and (2) are satisfied, and $t_{LH}/t_{LL} < w_{\mathrm{A}}/(1+\delta)$, so low-skill parents will have high-skill children the moment their country becomes advanced. Note that by allowing advanced countries to specialize in the H sector, free trade will lower their population growth relative to autarky.

The world population evolves according to:

$$N_{\mathrm{A},t+1} = \left(\gamma_{\mathrm{A}} + p(A(1-\alpha)/(1+\delta))^{1/\alpha} + i\right) N_{\mathrm{A},t}, \tag{5}$$

$$N_{\mathrm{D},t+1} = \gamma_{\mathrm{D}} N_{\mathrm{D},t} - \left(p(A(1-\alpha)/(1+\delta))^{1/\alpha} + i\right) N_{\mathrm{A},t}. \tag{6}$$

The proportion of the world population in advanced countries will increase and the world economy will eventually move to the second stage where all developing countries are integrated into the world economy and produce in the modern sector if:

$$\frac{N_{\mathrm{A},t+1}}{N_{\mathrm{D},t+1}} = \frac{\left(\gamma_{\mathrm{A}} + p(A(1-\alpha)/(1+\delta))^{1/\alpha} + i\right)}{\gamma_{\mathrm{D}} - (p(A(1-\alpha)/(1+\delta))^{1/\alpha} + i)\frac{N_{\mathrm{A},t}}{N_{\mathrm{D},t}}} \frac{N_{\mathrm{A},t}}{N_{\mathrm{D},t}} > \frac{N_{\mathrm{A},t}}{N_{\mathrm{D},t}}$$

This will be the case if:

$$\frac{N_{\mathrm{A},t}}{N_{\mathrm{D},t}} > \frac{\gamma_{\mathrm{D}} - \gamma_{\mathrm{A}}}{p(A(1-\alpha)/(1+\delta))^{1/\alpha} + i} - 1, \tag{7}$$

from which follows:

Proposition 1. *If $N_{\mathrm{DM}} < N_{\mathrm{D}}$, then $N_{\mathrm{A}}/N_{\mathrm{D}}$ will increase over time if and only if Eq. (7) holds. If $N_{\mathrm{A}}/N_{\mathrm{D}} < \frac{\gamma_{\mathrm{D}} - \gamma_{\mathrm{A}}}{P(A(1-\alpha)/(1+\delta))^{1/\alpha} + i} - 1$, then $N_{\mathrm{A}}/N_{\mathrm{D}}$ will converge to zero.*

Condition (7) becomes less strict the lower γ_{D}, the higher γ_{A}, p, i, and A, and the lower α and δ. If $\gamma_{\mathrm{D}} - \gamma_{\mathrm{A}}$ is sufficiently small, the right-hand side of Eq. (7) is negative, $N_{\mathrm{A}}/N_{\mathrm{D}}$ will always increase, and the world economy will eventually reach the second stage. If the population growth differential is large, then the right-hand side of Eq. (7) is positive and $N_{\mathrm{A}}/N_{\mathrm{D}}$ will only increase if its starting level is sufficiently high to satisfy this inequality (at which point the transformation and migration processes will dominate the demographic one). If $N_{\mathrm{A}}/N_{\mathrm{D}}$ is less than the threshold, then $N_{\mathrm{A}}/N_{\mathrm{D}}$ will decline indefinitely, converging to zero.

It's worth noting that if $N_{\mathrm{A}}/N_{\mathrm{D}}$ is below the threshold given in Eq. (7), then some countries will remain forever stagnant. In other words, the steady-state is not being driven by an infinitesimal fraction of developing countries with exploding populations. Development prospects worsen over time not only for any given habitant of the developing world, but also for any given developing country.

[5] A benevolent social planner would like to tax the traditional sector in order to subsidize the modern one.

Proposition 2. *If N_A/N_D is non-infinitesimally smaller than the threshold in Eq. (7), the modern sector will never reach a non-infinitesimal share of developing countries.*

Proof. See Appendix A. □

3.2. Stage 2: All countries are integrated into the world economy

Once the world economy moves to this stage where all workers are in the modern sector (i.e., $N_{DM}=N_D$), then:

$$\frac{N_{A,t+1}}{N_{D,t+1}} = \frac{(\gamma_A + i)N_{A,t} + pN_{D,t}}{(\gamma_D - p)N_{D,t} - iN_{A,t}} = \frac{(\gamma_A + i) + p/\left(N_{A,t}/N_{D,t}\right)}{(\gamma_D - p) - iN_{A,t}/N_{D,t}}\frac{N_{A,t}}{N_{D,t}}$$

and the N_A/N_D ratio will increase if:

$$i(1 + N_A/N_D) + p\left(1 + \frac{1}{N_A/N_D}\right) - (\gamma_D - \gamma_A) > 0 \tag{8}$$

The expression above is a convex second-degree polynomial in N_A/N_D If:

$$i + p - 2\sqrt{ip} < \gamma_D - \gamma_A < i + p + 2\sqrt{ip}, \tag{9}$$

then the roots of the polynomial are complex and the ratio N_A/N_D will grow without bounds.[6,7] The condition above is satisfied for the empirically relevant parameter values, as shown in Section 6. Even if Eq. (9) does not hold, as long as:

$$(A(1-\alpha)/(1+\delta))^{-1/\alpha} > \frac{\gamma_D - \gamma_A - i - p + \sqrt{(\gamma_D - \gamma_A - i - p)^2 - 4ip}}{2i}, \tag{10}$$

then the largest real root of Eq. (8) is lower than the N_A/N_D ratio at the beginning of the second stage, and N_A/N_D still grows without bounds. Condition Eq. (10) is more likely to hold when $\gamma_D - \gamma_A$ is small vis-à-vis $i+p$.[8] If neither Eq. (9) nor Eq. (10) holds, then the N_A/N_D ratio converges to a steady-state level given by:

$$\max\left((A(1-\alpha)/(1+\delta))^{-1/\alpha}, \frac{\gamma_D - \gamma_A - i - p - \sqrt{(\gamma_D - \gamma_A - i - p)^2 - 4ip}}{2i}\right). \tag{11}$$

Thus:

Proposition 3. *If $N_{DM}=N_D$, then $N_A/N_D \to \infty$ if either Eq. (9) or Eq. (10) hold and N_A/N_D converges to Eq. (11) otherwise.*

Regardless of whether N_A/N_D grows without bounds or converges to a steady-state level, once the world economy moves to the second stage where all developing countries are integrated and produce in the modern sector that will remain the case from that point onwards (i.e., they will never switch back to the traditional technology).[9]

Since in this stage all developing country workers are producing in the modern sector, the value of their labor is no longer pinned down by its opportunity cost in the traditional sector. Their wages will rise to reflect that scarcity (but developing country workers will continue to bear the cost δ). As long as workers in advanced countries remain sufficiently scarce that they only produce the H good, the wages in advanced and developing countries are:

$$w_A = A\alpha(N_D/N_A)^{1-\alpha}, \tag{12}$$

$$w_D = A(1-\alpha)/(N_A/N_D)^{\alpha} - \delta, \tag{13}$$

which are increasing in the relative scarcity of the respective type of labor. If N_A/N_D continues to increase, developing country labor will become sufficiently scarce that advanced country workers will move to the L sector. When w_A declines to $(t_{HH}/t_{HL})(w_D+\delta)$, which is reached at $N_A/N_D=(t_{HL}/t_{HH})\alpha/(1-\alpha)$ parents in advanced countries will stop educating some of their children. That is, their fertility choice model will move to the internal solution.[10] If the high-skill workers are in an internal solution, this new advanced country low-skill population will be at a corner where they only have low-skill children. In steady-state, the fertility choice of low-skill workers in advanced countries must be at an internal solution (otherwise their relative share would increase indefinitely), so in the long-run:

$$w_{A,H} = (t_{LH}/t_{LL})w_{A,L} \tag{14}$$

$$w_{A,L} = w_D + \delta \tag{15}$$

4. Differences across developing countries

This section introduces differences in the transaction cost between developing countries. We initially consider infinitesimal differences, and later analyze the implications of larger differences.

4.1. Infinitesimal differences

The arbitrarily small differences assumed in the transaction cost δ_c will not affect the evolution of aggregate populations in advanced and developing countries, but will have strong implications for which developing countries will grow first. Advanced countries will only import L from the developing countries with the higher transaction costs once all of the countries with the lower transactions costs have already joined the modern sector, placing countries in a development "queue." The cost δ_c can encompass variation in transaction costs across developing countries due to policy-related costs, such as tariffs, enforcement of property rights and contracts, distortionary effects of taxation and regulation, and corruption, among others. An individual country can benefit greatly from a small decrease in its cost δ_c, since its growth depends on the ordinal rank of δ_c (e.g., a small improvement can move it to the front of the queue). However, a similar improvement by all developing countries would only translate in a commensurately small improvement for global growth. That is, while infinitesimal changes in δ_c can rearrange the countries' positions in the development queue, the speed at which countries graduate from that queue (which is constrained by the population in advanced countries) will only improve slightly following small changes in the average δ. This can help explain growth failing to pick-up in the developing world as a whole despite significant improvements in policy over the last decades (as documented in Easterly 2001). The model also suggests a non-linear impact of policy reforms in individual countries, with growth

[6] Note that even though N_A/N_D grows without bounds, the share of high-skill workers will not (since some workers in the advanced countries will eventually switch to the L sector as described below).

[7] If N_A/N_D grows without bounds, eventually its growth will be lower than the one indicated by Eq. (8). For example, at some point $N_D < iN_A$ (i.e., even if all the remaining population in developing countries migrates to the advanced ones, they would still account for less than a share i of the latter).

[8] Note that the right-hand side is negative when $\gamma_D - \gamma_A < i + p$, implying N_A/N_D will grow without bounds (assuming that Eq. (9) does not hold, otherwise it would already grow without bounds to begin with).

[9] If that was not the case, then (7) would not hold, and the world economy would have never moved to the second stage to begin with. Note that if the world economy had initially started in the second stage, then it would be possible for it to switch to the first one (for example, if the population growth differential is sufficiently large).

[10] Note that as parents in advanced countries start having low-skill children, γ_A will increase.

potentially responding dramatically if the reforms move a country to the front of the queue but not otherwise.

These strong threshold effects are partly driven by the simplifying assumptions of our model. Since countries are identical except for small differences in their transaction costs, all variation in the order in which they join the modern sector will inevitably hinge on those small differences in cost. If the model was extended to allow the transaction cost to increase with the size of the country's population working in the modern sector, or diminishing returns in the production of L, we could have an internal solution where all developing countries join the modern sector to some extent. If the transaction cost were to decline with the share of the population employed in the modern sector (for example, if it stems from a fixed cost that gets increasingly diluted), the threshold effect would become even stronger.

4.2. Large differences

If transaction cost differences across countries are significant, the process of global integration will slow down as it reaches increasingly more costly developing countries. Suppose there are two types of developing countries: Low-cost developing countries, where $\delta_c = \delta_0 = \delta$; and high-cost ones where $\delta_c = \delta_1 > \delta$, but $\delta_1 < A/2 - 1$. The modern sector will initially hire workers form the low-cost developing countries. As long as there is an excess supply of workers in these low-cost countries, the world population in advanced and developing countries will evolve according to Eqs. (5) and (6) regardless of how the immigration "quota" is split between the low and high-cost developing countries. If Eq. (7) holds, the transformation process will dominate the demographic one, the initial share of the world population living in advanced countries will increase over time and eventually all low-cost developing countries will be absorbed by the modern sector. Once that happens, the transformation process will slow down as the modern sector moves to high-cost developing countries. It is easy to show that the world population will continue to evolve according to Eqs. (5) and (6) but with δ_1 instead of δ, and the proportion of the world population living in advanced countries will continue to increase provided:

$$\frac{N_A}{N_D} > \frac{\gamma_D - \gamma_A}{p(A(1-\alpha)/(1+\delta_1))^{1/\alpha} + i} - 1$$

If the condition above holds, then the modern sector will eventually spread to all developing countries. If it does not (and Eq. (7) holds), then the proportion of the world population living in advanced countries will converge to zero. Once the modern sector reaches the high-cost developing countries, the workers in the low-cost developing countries will earn a wage premium (their wage will increase from 1 in the initial stage to $1 + \delta_1 - \delta$, with further increases once all developing country labor has been integrated into the modern sector).

4.3. Very large transaction costs

It is interesting to consider an extreme case where $\delta_1 > A/2 - 1$. This assumption implies that the high-cost countries will never be integrated into the global economy, because the advanced economies would rather produce L themselves than transact with these developing countries. Again, as long as Eq. (7) holds, the world economy will eventually move to a stage where all low-cost developing country labor has been integrated into the modern sector, and all those low-cost developing countries will eventually become advanced countries. Since the high-cost developing countries will never be integrated into the modern sector, in the absence of migration, the share of the world population living in these countries would grow indefinitely since $\gamma_D > \gamma_A$. However, migration from these countries to advanced ones can still compensate for the natural population growth differential if N_A/N_D is sufficiently large for migration to overcome the population growth differential.[11] In fact, the long-run equilibrium will depend entirely on the demographic parameters and the N_A/N_D ratio at the time the world economy enters this stage. Provided:

$$N_A / N_D > (\gamma_D - \gamma_A - i) / i, \tag{16}$$

the global economy will still converge to widespread prosperity. Note that this condition is sufficient for the right-hand-side of Eq. (8) to be positive (if the global economy converges to prosperity despite the "hopeless" developing countries, it would still do so in our baseline model where the differences in transaction cost are small).

5. Extensions: Aid flows and agricultural commodity prices

5.1. Aid

A number of additional factors that can affect global development prospects can be easily introduced in our basic setting. For example, suppose that foreign aid flows are a proportion α of the advanced world's GDP, and that each unit spent succeeds in transforming a developing country with probability p_a. In this modified setting, all of the previous equations would hold if we substitute the terms involving i with $i + aw_A p_a$. In the initial stage, where not all developing countries are integrated into the modern sector, w_A is constant, given by Eq. (4). In the second stage, where all developing countries have been integrated (or at least all the "non-hopeless" ones), w_A is given by Eq. (12) which is a decreasing function of N_A/N_D.[12] In both cases, the presence of this additional channel can only help the global economy, and will increase the range of parameters for which widespread prosperity is achieved.[13]

5.2. Agricultural commodity prices

The increase in commodity prices leading to their mid-2008 peak renewed interest on the effects of an expanding global economy on the terms of trade of developing countries specializing in natural resource intensive sectors. While the treatment of the traditional sector in our model does not allow for any such improvements (since it is a perfect substitute for the modern good), a simple variant of that basic model can capture such effects for the case of agricultural commodities.[14]

Suppose each person must consume at least s units of the traditional good (where $s < \phi < 1$). Beyond that subsistence constraint, we continue to assume that the traditional and modern sector goods are perfect substitutes. We assume that trade is costless across countries (we can still assume $\delta > 0$ due to non-transportation related transaction costs, such as poor institutions for protecting property rights). This subsistence constraint implies:

$$\phi(N_D - N_{DM}) \geq s(N_D + N_A) \tag{17}$$

where the left-hand-side corresponds to the traditional sector output and the right-hand-side to the global subsistence demand.

If N_A/N_D is sufficiently small to begin with, Eq. (17) will be satisfied with the amount of developing country labor hired into the modern sector (3) from the baseline model, and the evolution of the global economy is still described by Eqs. (5) and (6).

[11] These hopeless developing countries are similar to the "ghost countries" in Pritchett (2006).

[12] If the world reaches the stage where there are both high- and low-skill workers in advanced countries, the term $aw_A p_a$ would be based on their average wage.

[13] If one takes a negative view on the role of aid, one could assume the parameter α to be negative, in which case this additional channel could hurt the long-run dynamics.

[14] An analysis of mineral commodities would be complicated by their exhaustible nature.

As N_A/N_D grows, the constraint (17) will eventually bind, which occurs for:

$$\frac{N_A}{N_D} = \frac{\phi - s}{\phi(A(1-\alpha)/(1+\delta))^{1/\alpha} + s} \tag{18}$$

From that point onwards, $N_{DM} = \max(0,(\phi - s)N_D - sN_A)$ and the populations in the advanced and developing world will evolve according to:

$$N_{A,t} = (\gamma_A + i)N_{A,t} + p\max\Big(0,(\phi - s)N_{D,t} - sN_{A,t}\Big)$$
$$N_{D,t} = \gamma_D N_{D,t} - iN_{A,t} - p\max\Big(0,(\phi - s)N_{D,t} - sN_{A,t}\Big)$$

Since Eq. (17) binds, the value of the traditional good is no longer 1. The value of that output will equal the value of the wage w_D that workers can achieve in the modern sector. As in Section 3.2, the wages of developing country workers in the modern sector will start increasing to reflect scarcity of their labor. But unlike in the baseline model, the wages in the traditional sector will now grow in tandem with w_D.

Our assumptions imply that the terms of trade for developing countries will only start improving if N_A/N_D is sufficiently large. This assumption is consistent with the trends (or lack thereof) in commodity prices. For example, the real price of food commodities at their 2008Q2 peak was still 25% lower than its 1960 level.[15]

The higher returns in the traditional sector will slow down the transformation process, but will improve the contemporaneous welfare of the developing countries that remain outside of the modern sector.[16]

As in Section 3.2, as the global economy grows, workers in the advanced country will eventually start producing L, and relative wages will converge to Eqs. (14) and (15). But in this modified setting, further convergence can occur. If N_A/N_D continues to grow, we will reach the point where developing country labor becomes so scarce that it cannot meet the global subsistence constraint and advanced country workers move back to the traditional technology (where they are both equally productive), and $w_{A,L} = w_D$. That occurs when:

$$N_A / N_D \geq (\phi - s)/s$$

These terms of trade effects could weaken if we were to consider productivity gains in the traditional sector. Even if we introduce productivity growth in both sectors, and productivity in the traditional sector grows slower than that in the modern sector, that could remove these terms of trade effects (since they hinge on the subsistence constraint being binding), at least for some ranges of parameters.

6. A simple calibration

This section calibrates the model. We classify countries as advanced or developing and describe the historical evolution of the ratio of their populations. Then, using the analytical framework of Section 2 we simulate the future evolution of the world economy considering a number of alternative scenarios for demographic parameters and the transformation rate.

We use population and GDP data from Maddison (2003) for 1820–2001 and classify economies as advanced using as a guideline whether their GDP per capita, measured in 1990 International Geary–Khamis dollar terms (a PPP based measurement), was higher than one-third of that of the "leading country," defined as the United Kingdom for 1820–1900, and the United States afterwards.[17] Since the model assumes one-way transitions from developing to advanced, we only classify as advanced the economies that permanently cross that threshold. Former communist countries were always considered developing prior to their transition to a market economy and so are countries whose permanent high income can be attributed to mineral resources. Table 1 lists the economies classified as advanced and the year that classification was assigned, and provides detailed explanations on the classification of countries that crossed the threshold more than once.

Table 1
Economies classified as advanced and year classification assigned.

Economy	Year	Economy	Year
Austria	Entire sample	Australia	1822
Belgium	Entire sample	New Zealand	1846
Canada	Entire sample	Finland	1869
Denmark	Entire sample	Japan	1932
France	Entire sample	Israel	1955
Germany	Entire sample	Hong Kong SAR	1963
Ireland	Entire sample	Puerto Rico	1963
Italy	Entire sample	Spain	1963
Netherlands	Entire sample	Greece	1965
Norway	Entire sample	Portugal	1970
Sweden	Entire sample	Singapore	1972
Switzerland	Entire sample	Taiwan Province of China	1982
United Kingdom	Entire sample	Korea	1988
United States	Entire sample	Czech Republic	1990
		Estonia	1990
		Slovenia	1990
		Mauritius	1992
		Chile	1995

Notes: Classification based on methodology described in Section 3 for calibrating the model. Income data from Maddison (2003), covering 1820–2001. Data for Australia and New Zealand available only every 10 years during 1820–70. Their transition years were estimated by interpolation. Only countries that crossed the income threshold and remained above it throughout the rest of the sample were classified as advanced. Advanced countries that crossed the income threshold multiple times were classified based on the initial crossing date only if the temporary decline lasted 3 years or less (for example, Finland in 1880–82) or can be attributed to a major war: Austria: 1945–48, Finland: 1917–20 and 1943–45, France: 1942–45, Germany: 1946–48, Ireland: 1942–46, Italy: 1943–47, Japan: 1942–59, Netherlands: 1944–45 and Norway: 1944. The following countries experienced prolonged periods of income above the threshold prior to being classified as advanced: Chile: 1900 (or earlier)–1942 and 1946–72, Greece: 1820–50 (or later) and 1921 (or earlier)–22, 1925 and 1927–39, Portugal: 1820–55 (or later), 1932–34 and Spain: 1820–1936. Countries whose continuing high income can clearly be attributed to mineral resources were not classified as advanced: Kuwait, United Arab Emirates and Trinidad and Tobago, which crossed the threshold in 1950 or earlier and Equatorial Guinea which crossed it in 2001. Income data from communist countries were not considered. A number of countries were temporarily above the income threshold, but later permanently decline below it. The main cases were Argentina: 1870 (or earlier)–1984, 1986–87, 1993–94 and 1997–98, and Uruguay: 1870–1966, 1970–71, 1980–81. Venezuela was above the threshold during 1926–98 (but its high income can be attributed to oil). Other noteworthy cases are Czechoslovakia which had been above the income threshold since 1820 at the time it became a communist country, and Hungary: 1870 (or earlier)–1913 and 1925–1940.

The N_A/N_D ratio increased throughout the 19th century even though only Australia, New Zealand, and Finland joined the advanced economy group, because population growth in advanced economies was considerably higher than that in developing ones (see Figs. 1 and 2). In the early 20th century population growth in developing countries increases substantially, at least in part due to the development of health technology allowing substantial reduction in mortality at low income levels.[18] Following this reversal in the demographic trends, N_A/N_D gradually declines through the 20th century, with blips when major transitions occurred (notably Japan in 1932, and to a

[15] Based on IFS data deflated by the U.S. GDP deflator.

[16] While this higher wages benefit the lagging developing countries today, they can move the global economy from an equilibrium where N_A/N_D rises indefinitely to one where it converges to Eq. (18). How that would be weighted against this higher contemporaneous wages would depend on the discount factor used.

[17] Basing the comparison on the income of the leading country as opposed to say the world average is more suitable to our model and it avoids causing the income threshold to mechanically increase as more countries develop.

[18] Population growth declined in advanced countries beginning in the early 20th century, and later have declined even in developing countries. This is likely due to a number of factors, but rising investment in education has certainly contributed to this trend.

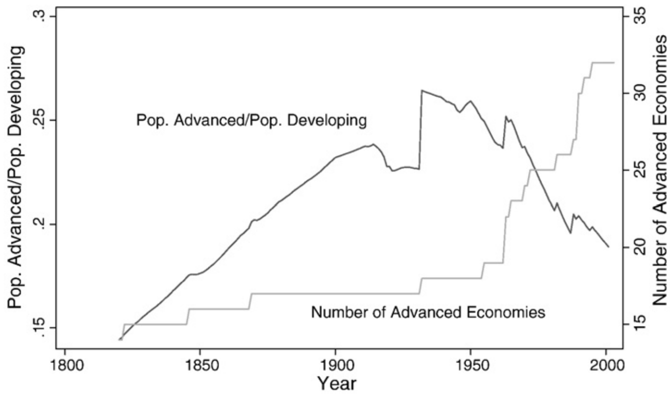

Fig. 1. Ratio of world population in advanced and developing economies and number of advance economies. Notes: Data from Maddison (2003). Missing observations log-linearly interpolated.

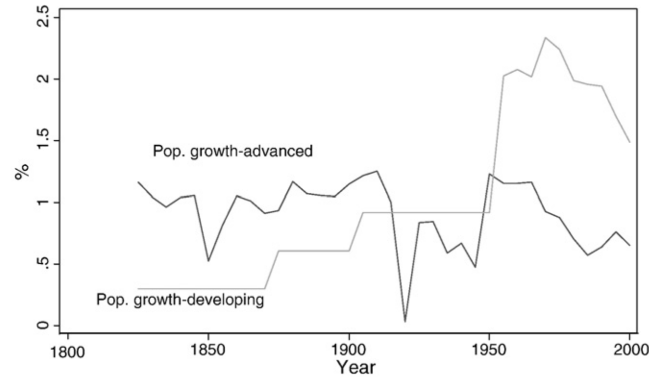

Fig. 2. Population growth in advanced and developing economies from 1820 to 2000. Notes: Data from Maddison (2003). Plot indicates (geometric) average growth over 5 year period ending in that year. Missing observations were log-linearly interpolated.

smaller extent Spain in 1963, Taiwan Province of China in 1982, and Korea in 1988). Note that N_A/N_D declined despite a substantial increase in the number of advanced economies. An increase in the number of transformations relative to earlier periods is consistent with the endogenous transformation in our model.

The limited number of transitions in the 19th century and in the first half of the 20th century, particularly in comparison with those in the second half of the 20th century, suggests some parameters must have changed dramatically. There has indeed been a large decline in transport costs (O'Rourke and Williamson, 2002). That, combined with an increase in the complexity of supply chains, have likely facilitated splitting the production into complex and simple tasks in a way that the latter can be performed in developing countries.[19] It is plausible that the transaction costs embodied in δ were very high in the 19th century, to the point that most of the developing world modern sector trade and learning opportunities were lost.

Since transitions from the developing to the advanced economy group are rare, $p(A(1-\alpha)/(1+\delta))^{1/\alpha}$ is estimated by averaging over the last 50 years in the sample (1952–2001) the ratio of the population in the economies that just became advanced to the total population in advanced economies in that year. That yields an estimated $p(A(1-\alpha)/(1+\delta))^{1/\alpha}$ of 0.40%. The average for the 20th century as a whole is 0.37% (the average for the first half is 0.34% and for the second half is 0.40%).[20] As expected, the countries that did succeed in becoming advanced economies were on average more open. In the years where transitions occurred, the average ratio of exports and imports to GDP was 92% for the transitioning country compared with an average (weighted by GDP) of 38% for the remaining developing countries.

Data on population and migration is available for 1950–2005 through the United Nations Population Division, which also provides forecasts for every fifth year up to 2050. Based on this data, we compute the natural population growth rates γ_A, γ_D and the migration rate i. Both γ_A and γ_D have declined over time, but beginning in the 1990s, the decline in γ_D has accelerated and the $\gamma_D-\gamma_A$ gap has substantially narrowed and is expected to continue to do so, albeit at a slower rate (see Fig. 3). Based on 2000–05, the estimated parameter values are: $\gamma_A=0.29\%$, $\gamma_D=1.38\%$ and $i=0.31\%$. The i estimate includes only developing to advanced economy migration (i.e., it excludes migration from one advanced economy to another).

Based on the demographic parameters above, and $p(A(1-\alpha)/(1+\delta))^{1/\alpha}=0.40\%$, the right-hand side of Eq. (7) is 0.52, which is higher than the 2005 N_A/N_D ratio of 0.17, suggesting that the proportion of the world population living in developing countries would grow indefinitely.

Fig. 4 plots the evolution of N_A/N_D excluding China and India under the baseline scenario and under alternative demographic parameters and transformation rates (we plot that ratio excluding China and India for comparison purposes with alternative scenarios focusing on developments in those two countries later in this section). If the gap in population growth rates between advanced and developing economies narrows according to the projections of the UN Population Division, the world economy will eventually converge to the prosperous steady-state (conditions (7) and (9) would hold). However, that convergence process would be extremely slow and no substantial improvements would take place within a century. As shown in Fig. 4, the long-run dynamics could substantially improve through halving natural population growth disparities, doubling immigration or doubling the transformation rate. The transformation rate could potentially change due to improvements in communication and transportation or policy improvements. The share of exports and imports on GDP aggregated across the developing countries in our

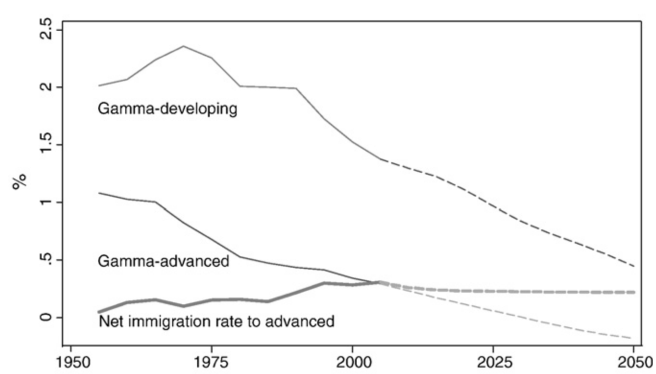

Fig. 3. Natural population growth and net migration from 1950 to 2005 and projections for 2005 to 2050. Notes: Data from the United Nations Population Division. Plot indicates average migration rate and the (geometric) average growth rate over the 5 year period ending in that year. Solid lines indicate actual values and dashed lines indicate projections.

[19] For example, the scope for breaking-up the production of steel or textiles in the 19th century across countries is far more limited than the one for breaking-up the production of laptop computers and auto parts nowadays.

[20] As indicated in Table 1, the only transition from developing to advanced in the first half of the 20th century was Japan in 1932. Japan's income declined below the advanced status threshold during 1942–1960 as a result of the devastating effects World War II had on its economy. If we had classified Japan as a developing economy until 1960, the resulting estimate of $p(A(1-\alpha)/(1+\delta))^{1/\alpha}$ for the second half of the 20th century would increase to 0.79%. This higher transformation rate would suggest better prospects for developing countries (and would also suggest that development has become "easier" from the first to the second half of the 20th century).

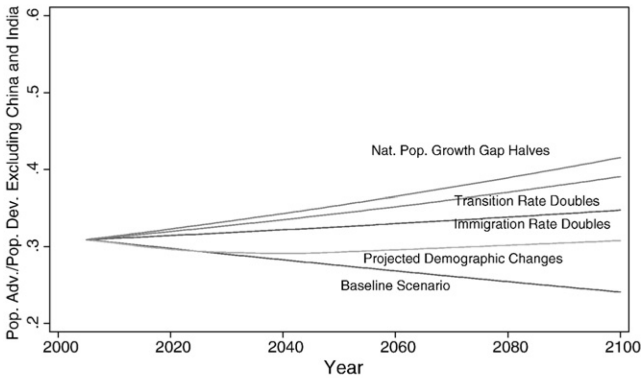

Fig. 4. Evolution of the ratio of the world population in advanced economies to the population in developing economies, excluding China and India, under different scenarios. Notes: All simulations assume the world economy remains in the stage where not all developing countries produce in the modern sector. The baseline scenario corresponds to demographic parameter values as of 2000–2005, and the historical transition average based on 1952–2001. Projected demographic changes are available through 2050 and parameters values for later years are held constant at their projected 2050 level.

sample has increased from 22% in 1960 to 65% in 2005. While this is a somewhat crude measure of openness, this trend does suggest increasing opportunities for global economic integration.

This calibration exercise has considered the world economy as a large collection of small countries, whose evolution can be approximated by a smooth and deterministic process. In practice, the transformation of large countries could move sizable shares of the world population from poverty to prosperity. Perhaps the most optimistic interpretation of the model is one in which rapid growth in China and India is seen as a transition to advanced country status in progress. Holding other parameters constant, if China became an advanced country today the N_A/N_D ratio would jump to 0.54, moving it just above the critical threshold. Condition (9) would hold under the baseline parameter values so eventually N_A/N_D would grow without bounds. If both China and India became advanced economies, the N_A/N_D ratio would jump to 1.09.[21] Fig. 5 plots the effects of China and of China and India instantaneously becoming advanced economies. In the scenario where both China and India become advanced countries there is a noticeable acceleration in the rate at which other economies develop. This illustrates one of the key features of our model, whereby the higher the population in advanced countries the easier it is for the remaining developing countries to integrate in the world economy. Thus, even if China and India are at the front of the development queue, that could actually benefit other developing countries in the long-run provided these giants transform sufficiently rapidly.

An even more optimistic outlook can be obtained if we adjust the transformation rate to reflect the view that China and India are a transition in progress. For example, even if China was the only country to transition from developing to advanced in the next 50 years, that single transition by itself would imply $p(A(1-\alpha)/(1+\delta))^{1/\alpha}=$ 2.80%, a seven-fold increase relative to our baseline value.[22] Such adjustment would be consistent with the view that a similar transformation to the one going on in China can take place in other developing regions (i.e. there is nothing inherently special about China other than perhaps being ahead in the development queue). That increase in the transformation rate would lead to a dramatic acceleration in global development, far stronger than when China and India instantly become advanced (and the transformation rate is kept at its baseline value). Fig. 5 shows that even under the more "conservative" assumption that the transformation rate "only" triples, it would still lead to gains to the rest of the world similar to those achieved when China and India instantly develop.

If some developing countries are "hopeless" like the high-cost countries discussed in Section 4.3, based on the 2050 projection for the demographic parameter values, the N_A/N_D would need to grow past 1.85 in order to ensure a prosperous steady-state. In the scenarios where both China and India instantaneously become advanced, such high ratios would be achieved towards the end of the 21st century, assuming that the transformation process continues to spread until then. A five-fold increase in the transformation rate (in the absence of instant development in China and India) could also bring N_A/N_D past that threshold towards the end of the 21st century.

7. Conclusion

This paper presented a simple model of trade and development where the prospects for developing countries depend on integration with the world economy. The opportunities for integration improve as the population in advanced countries grows. As developing countries become advanced economies, they no longer compete for export markets with other developing countries, and instead will import from them. This can lead to accelerating global development and widespread prosperity if the difference in population growth rates in advanced and developing countries is small. If that difference is large, widespread prosperity will hinge on whether or not the current share of the world population in advanced countries is above a critical threshold necessary for the transformation and migration processes to dominate the demographic trends.

The model also yields strong non-linearities for growth across countries, where small differences in transaction costs associated with trade can have major implications for which developing countries will grow first. Those combined costs, which can encompass different aspects, including policy-related costs, will rank countries ordinally along a queue where they will wait for their chance to join the global economy. While policy improvements can move an individual country forward in that queue, the developing country labor that can be absorbed by the global economy is ultimately constrained by the size

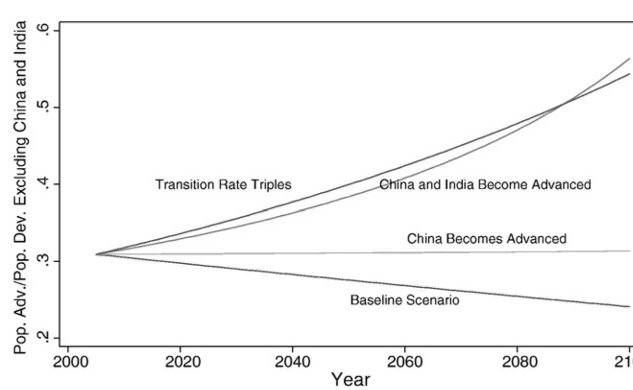

Fig. 5. Effect of China and India instantaneously becoming advanced economies on the rest of the world. Notes: Plot indicates evolution of the ratio of the world's population in advanced countries to the population in developing countries excluding China and India. All simulations assume the world economy remains in the stage where not all developing countries produce in the modern sector. The baseline scenario corresponds to demographic parameter values as of 2000–2005, and the historical transition average based on 1952–2001.

[21] If we update Maddison's 2001 PPP per capita GDP figures based on per capita GDP growth at constant local currency prices, in 2007 China's per capita income was 20% of that in the U.S. while India's was only 9%. Even under the assumption of an 8% per year growth in (PPP) per capita income in China and India and a 3% per year growth in the U.S., per capita income in China would only reach 1/3 of the U.S. level in 2019, and in India only in 2035.

[22] This value is based on the current ratio of China's population to that in advanced economies. Since population growth is higher in China than in the latter, the implied transformation rate would be even higher if based on their projected future populations.

of the population in advanced countries. As a result, an individual country's growth response to a policy improvement can be much larger than the global growth response to a similar improvement in all developing countries. This can explain why growth has not increased substantially despite dramatic improvements in the economic policies of several developing countries. These results also have interesting implications for the growth prospects of lagging developing regions, such as Africa. It is possible that Africa's prospects will remain limited over the short- and medium-term if it lies behind China and India in the "development queue." But Africa's prospects should improve substantially in the long-run once labor becomes "expensive" in China and India, or if continuing global development leads to a sustained improvement in their terms of trade.

The non-linearities in the growth process and threshold effects proposed in this paper suggest caution should be used when extrapolating the existing empirical evidence on economic growth into the future. Over short horizons, these results are likely to exaggerate the developing world-wide benefits of policy improvements, as some of the observed growth may come at the expense of other developing countries if the queuing effects described are at play. Over longer horizons, these empirical results are likely to be over-pessimistic, as country characteristics that lead to low growth today may allow for high growth if and when the global economy reaches a sufficiently advanced stage. For example, the same policies that make a country unattractive to foreign investors today may not discourage them from investing in the future if that country becomes one of the last places in the world where labor is still "cheap." But if there are countries whose policies are so bad that they would never successfully integrate into the global economy, then the conditions required to ensure widespread prosperity in the long-run become much stricter, since migration would be the only route to prosperity for the population in these hopeless developing countries.

The old conventional wisdom was that population growth in developing countries was a major problem. The new conventional wisdom is that population growth is rapidly declining and hence not an obstacle to development. Our results highlight the importance of relative population growth between rich and poor countries. Because population growth has been declining in both the rich and the poor world, the differential is relatively persistent. It's worth noting that in our model, population growth in developing countries will create negative externalities on other countries, while population growth and open immigration policies in advanced countries will create positive externalities. The model suggests that the future of the world economy may well be decided by a race between rapid economic growth in China and India and population growth in the lagging developing regions.

To end on a more positive note, while there have been relatively few cases of developing countries that became rich (mainly a handful of East Asian and Southern European countries), one can make a strong case that a number of key developing countries (in addition to China and India) are on track towards becoming advanced economies over the next few decades. Global trade continues to grow faster than world GDP, and improvements in telecommunications and transportation should further facilitate the integration of developing countries in the global economy, as the lower these costs the easier it becomes to break-down the production process so that simpler tasks can be performed in developing countries. If that integration is indeed constrained by absorption capacity, as in our model, such a confluence of positive shocks can unleash non-linearities and lead to accelerating global growth at an unprecedented scale.

Appendix A

Proposition 2. *If N_A/N_D is non-infinitesimally smaller than the threshold in Eq. (7), the modern sector will never reach a non-infinitesimal share of developing countries.*

Proof. Let $\tilde{N}_D$ denote the population in the developing world we would observe if there were neither transitions nor migration: $\tilde{N}_{D,t} = N_{D,0}(\gamma_L)^t$.

Let $C_{D,0}$ denote the initial measure of developing countries, and $\tilde{n}_D$ the population in each of those countries. Similarly, let $C_{D,t}$ denote the measure of developing countries in our model (with transitions and migration) as of date t, and n_D the population in each of those countries. Thus:

$$\tilde{N}_{D,t} = \int_0^{C_{D,0}} \tilde{n}_{D,t} dc, \text{ and } N_{D,t} = \int_0^{C_{D,t}} n_{D,t} dc$$

The population of a developing country in our model is smaller than it would have been in a world with neither transitions nor migration ($n_{D,t} \leq \tilde{n}_{D,t}$).[23] Thus:

$$\frac{C_{D,t}}{C_{D,0}} \geq \frac{N_{D,t}}{\tilde{N}_{D,t}} \tag{19}$$

For simplicity of notation, let $p' = p(A(1-\alpha)/(1+\delta))^{1/\alpha}$. Solving the system Eqs. (5) and (6) we obtain:

$$N_{D,t} = \frac{N_{A,0}(1+p')(i+p+\gamma_A)^t - \left(\left(N_{D,0}+N_{A,0}\right)(1+p') + N_{D,0}\gamma_H\right)\gamma_D^t - N_{D,0}\gamma_D^{1+t}}{\gamma_D - \gamma_A - p' - i} \tag{20}$$

Substituting Eq. (20) on Eq. (19) we obtain:

$$\frac{C_{D,t}}{C_{D,0}} \geq \frac{N_{A,0}(1+p')(i+p+\gamma_A)^t - \left(\left(N_{D,0}+N_{A,0}\right)(1+p') + N_{D,0}\gamma_H\right)\gamma_D^t - N_{D,0}\gamma_D^{1+t}}{(\gamma_D - \gamma_A - p' - i)N_{D,0}(\gamma_D)^t}$$

If $\gamma_D > \gamma_A + p' + i$:

$$\lim_{t\to\infty} \frac{C_{D,t}}{C_{D,0}} \geq 1 - \frac{(p'+i)N_{A,0}/N_{D,0}}{\gamma_D - \gamma_A - p' - i} > 0$$

The ratio above converges to zero as $N_{A,0}/N_{D,0}$ converges to the threshold in Eq. (7). Since $N_{A,0}/N_{D,0}$ is non-infinitesimally below that threshold, the share of developing countries that are never reached by the modern sector is non-infinitesimally. □

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[23] If it were not for migration they would be identical.

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