

Sustainable Development and Globalization in a World with Unequal Starting Points

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ABSTRACT

We develop a simulation model, borrowing from and integrating aspects of economics, demography, and environmental and political science, to simultaneously consider environment, economic development, and population/politics by focusing specifically on the impact of important flows (i.e., pollution, capital, technology, production goods, natural resources, and people). The model can assess sustainable development on three levels: economic (by determining production, consumption, investment, direct foreign investment, foreign aid, technology transfer, and international trade), social (by calculating population growth/change, migration flows, and political stress levels), and environmental (by calculating natural resource use and the difference between environmental pollution and upgrading expenditures). We use the model to explore the challenges of development for countries with different initial conditions (i.e., natural resource endowment, physical and human capital, technology, and population) in a world with movement of goods, people, and capital, free substitution in production, flexible economic structures, and the ability to upgrade input factors via investment.

We find that, rather than the total physical capacity of the earth being responsible for unsustainable paths, the initial disparities in circumstances among countries and the complex of internal and international human interrelationships can lead to a “social non sustainability”. The greatest challenge for rich countries (given their aging populations) is *maintaining sufficient* investment, and the greatest poverty trap for poor countries (given their subsistence consumption) is *attaining high* investment. The impact of globalization (i.e., the international flow of goods, people, and capital) on various countries differs depending on their starting points, and this relationship can change over time. The modal behavior of the model can be either convergence or divergence among countries depending on the extent of these global flows and the degree to which individual countries can manage them. In general, capital flows (when accompanied by technology transfer) tend to benefit all countries, migration tends to benefit the destination countries (particularly the aging, rich) and the migrants themselves, and the benefits of trade can be either positive or negative depending on country endowments.

Disclaimer

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1. Overview of Model

The model contains the following major segments: (1) a global economic system, covering seven significantly different “countries”; (2) an environmental natural resource system, relating environmental quality and natural resource capacity to welfare and economic production and consumption; and (3) induced changes in population growth and age distribution in each country (including international migration). The economic system comprises sets of relationships in different stages for each country: (1) production of three kinds of commodities (two final goods and one intermediate); (2) patterns of international trade and foreign direct investment; (3) determination of consumption and investment; (4) allocation of investment resources over five investment categories (physical capital, human capital, natural resource capacity, environmental quality upgrading, and development of new technology).

There are four types of decision-makers in the model: (1) all consumers; (2) owners of productive resources, i.e., workers and owners of physical capital and land (or the firms); (3) in each of seven countries, three separate production sectors (thus making 21 individual “firms” overall); and (4) an aggregate national “investor” for each country. The aggregate national investor allocates a country’s total investment pool among different types of investment, actually engages all those investment activities, determines the size of the total investment pool via a Keynesian investment function, and determines the market goods-environmental quality tradeoff (by choosing to spend on environmental quality upgrading).

Each type of decision-maker renders decisions via optimization. Consumers choose their consumption mix (between two final goods) to maximize their utility, derived from demand functions. The national optimal consumption mix is based on national utility maximization reflected in consumer goods demand. Since we have no interest in specific consumption preferences, we assume these demand functions all have unitary price and income elasticities; thus, budgetary allocations to these goods are constant and, for simplicity, are equal for the two goods in all countries. Each “industry firm” maximizes its profits. Since there is no leisure or operation-related depreciation, factor owners maximize period returns to their assets by supplying what is demanded. The national investor maximizes present discounted value of all investments performed in each period, based on the marginal productivity of different investment types and on national preference tradeoffs between market goods and environmental quality.

Each type of investment generates, via sectoral production functions and profit-maximizing levels of output, a lifetime marginal value productivity that is transformed into a present discounted value via a single social rate of discount specified for each country as a function of its per capita GDP. Relative rates of return form the basis of allocation. The size of the investment pool is given by a Keynesian consumption-investment function, modified by social provision for rates of population dependency.

The model sequentially, deterministically, and in discrete-time “periods” runs through (i) equilibria (individual country labor markets and internationally traded goods), (ii) optimizations (profit maximization, final goods consumption mix, and investment mix—including welfare-

maximizing goods consumption versus environmental quality choice), and (iii) updates (productive endowments, discount rates, and population—number, age structure, and mortality and fertility rates). Thus, at the end (and as a result) of this sequence of events, each country has a new set of input endowments and prices. In addition, there is a new set of international trade prices. In this manner the whole global system will generate 90-100-period (or year) national trajectories. To calibrate and test the limits of the entire model a series of *nested, two-level, full* and *fractional factorial* experimental designs were used. Factorial designs allow study of the effects of changes in levels of independent factors as well as of interaction effects. (This method is described in detail with examples in Schmidt and Launsby (1992).) In general, model behavior is not sensitive even to reasonably large changes in parameters. (There is numerical sensitivity to changes in some parameters; however, behavior robustness is most important for our findings.)

Assumed differences in our stylized countries have been chosen to show the importance of initial conditions on influential variables in generating different long-run outcome trajectories. The country initial conditions are based on judgmental stereotypes of Rich, Middle, and Poor countries, as enhanced by empirical data on country factor endowments; however, only the age structure and birth and death rates are taken directly from the empirical data of specific countries (from Keyfitz and Flieger, 1990). Since the different levels of development or per capita GDP (in our model and empirically) are essentially defined in terms of technology, human capital, and physical capital per capita, differences within each level of development refer to population size and resource (land) endowment. Middle countries differ as well in population growth rates.

So, there are two Rich countries, one with larger total population and higher resource endowment per capita; three Middle countries, varying in population, resource base, and population growth; and two Poor countries, differing in population size. The two Poor countries have the greatest resource endowment, followed by Middle3, then Middle2 and Rich2; Middle1 and Rich1 have the smallest resource endowment. The Rich countries' populations have low birth rates and advanced age structures (based on the European Community circa 1980). The three Middle countries use data from Venezuela in 1975, Chile in 1980, and Taiwan in 1985, and thus, vary in the degree to which they have undergone demographic transition. The Poor countries have high birth rates and young age structures (initial data from Guatemala in 1985). Table 1 shows the most important initial country endowments (these data—with the exception of TFRs and dependency ratios—as well as the simulation output, are “stylized” and in generic units applicable to the specific variables they describe, e.g., units of physical capital, production, consumption, etc.).

Place Table 1 here

2. Model Modules

2.1 Production module

In each country, there are three production sectors: resource intensive industry (producing a final good), resource nonintensive (“service”) industry (producing a final good), and natural resource extraction industry (producing an intermediate good). Final goods and processed natural resources are tradables, so their prices are the same for all countries; wage and rent rates are

determined locally. Because labor (but not capital) is completely mobile (within each country), countries can shift production each period for competitive advantage. Since the producers are treated as profit-maximizing price takers, and since physical capital is not sectorally mobile, the amount of each good produced by each country is a straight-forward optimization calculation. The local wage rate for each country clears the labor market each period. At the end of each period each country's rent rate on physical capital is updated by recalculating the average marginal value product of capital for the three sectors, weighted by the total amount of capital in each sector.

Lastly, world prices for the two final consumption goods and the intermediate, natural resource good are calculated for use in the following period. These prices are calculated iteratively by equating forecasted world supply and demand. This (arguably simplified) solution method results in actual global supplies and demands that equate within +/- one percent (after an initialization process taking from three to seven periods). The national aggregate adjustments in equilibrium have many lags, constraints, and uncertainties, making for varied speeds of adjustment. These adjustments are too complex to model simultaneously, so we simplify by adjusting prices at the end of each period, and leaving the direction of behavioral adjustments to these new prices to the next period. Adjustments, therefore, lead to continued temporal changes—a main focus in the model.

The production functions for the two final consumer goods sectors, with all variables and parameters specific to each period t , are:

Resource nonintensive service sector, S:

$$Q_S = T (HL_S)^{bls} K_S^{bks} R_S^{brs} \quad (1)$$

Resource intensive industry sector, I:

$$Q_I = T (HL_I)^{bli} K_I^{bki} R_I^{bri} \quad (2)$$

Where:

Q_S, Q_I : output for two sectors

T : input-neutral technological improvements (same for all sectors)

L_x, K_x, R_x ($x = S, I$) : labor, capital, natural resource input for individual sectors

H : human capital factor (same for all sectors)

bks, bls, brs ($x = s, i$) : productivity exponents for three inputs and two sectors.

The production function for the resource extraction sector, also specific to each period t , is:

$$R = ATK_R^{\alpha_{kr}} (HL_R)^{\alpha_{nr}} \overline{R}^{\beta} \quad (3)$$

Where:

R : amount of extraction

A : country specific factor representing land endowment

T : input-neutral technological improvements (again, same for all sectors)

L_R, K_R : labor and capital input

H : human capital factor (again, same for all sectors)

α_{kr}, α_{nr} : productivity exponents for capital and labor

$\bar{R}$: 8 year moving average of past extraction

β : country specific drag parameter based on the extent of recent extraction (less than -1).

The purpose of this formulation ($\bar{R}$ raised to the drag parameter) is to allow for heavy recent production to increase rapidly the cost of further extraction, as too much extraction degrades the resource base. (The formulation is not meant to model regeneration per se.) The drag parameter is constrained to be less than -1.0 because we believe past extraction should have an increasingly negative effect on productivity. This increasing cost to extract can lead to *increasing prices* for the natural resource, *despite its inexhaustibility*. This drag is reduced by lowering extraction temporarily. The land endowment coefficient can be increased via investment.

All the production functions are assumed to have constant returns to scale. The exponents used in Equations 1-3 were estimated from empirical data of factor shares using The OECD Input-Output Database (1995), as applied to the stylized definitions of our aggregate sectors. The resource intensive industry is less labor intensive than the resource nonintensive one. Table 2 shows the exponent values used in the simulation model (our results are similar to a number of other studies, e.g., Duchin and Lange, 1992; McKibbin and Wilcoxon, 1995; and Bernard and Jones, 1996).

Place Table 2 here

2.2 Investment module

The share of a country's total GDP allocated for investment depends positively on the country's per capita GDP relative to the initial per capita GDP of the richest country (a measure of a minimum consumption necessity), and negatively on the country's young (ages 0-14) and aged (65+) dependency (i.e., the ratio of those cohorts to the total population). This relationship is one of the most important in the model¹:

$$c = 0.34 + -0.071 \ln(GDP / GDP_0^R) + 0.7 \times pop(0-14) + 2.1 \times pop(65+) \quad (4)$$

where c is the fraction of GDP for consumption, GDP is per capita GDP, GDP_0^R is the initial per capita GDP of the Rich country, $pop(0-14)$ is the fraction of population aged 0-14, and $pop(65+)$ is the fraction of population over 65. The GDP ratio term as well as c are constrained (by other equations) to be less than or equal to one. (Because our model does not have a financial sector, countries must invest all income that is not spent on goods consumption in projects commencing in the current period; thus, Equation 4 does not have a term for the return on investment.)

The coefficients in Equation 4 were derived econometrically from panel data (observations in 1985 and 1990) from World Bank (1994). All of the coefficients are statistically

¹ The one exception to the model's lack of *behavioral* sensitivity occurs when the coefficients in Equation 4 are adjusted (by one standard deviation from their econometrically derived values) in the way that constrains investment the most. Under this scenario the rich countries' per capita GDP displays "growth and then collapse," as their share of income for investment eventually reaches zero (driven by their population aging).

significant at least at the five percent level (the adjusted R-squared for the regression was 0.42). We normalize the per capita GDP term (1) to render its impact indifferent to the magnitude of GDP and, thus, appropriate for the stylized values used in the simulation model, and (2) to lessen some of the regression problems common when the dependent variables are a combination of rates and levels. These results are similar to other econometric models, like Kelley and Schmidt (1994) and Mason (1987 & 1988); however, we attribute a greater drag on investment to aged dependency (perhaps because those analyses were only concerned with developing countries). Our formulation gives Middle countries (with per capita GDPs about one-fourth of Rich countries') an opportunity to invest, but gives Poor countries (with per capita GDPs 1/20 or less of Rich countries') very little chance to catch up.

Each type of investment has a distinctive production function and cost function. From these functions, rates of return are calculated for each investment type. (To project these production and cost functions over the life of an investment, current prices and factor endowments are assumed to be constant.) These different return rates determine the percentages of the total investment pool that are allocated to each investment type via a logit share equation (thus, investment funds are allocated in proportion to their relative returns).

Each country's discount rate, at the end of each period, is adjusted linearly for changes in per capita GDP. Initially, the Rich countries' discount rate is five percent, the Middle countries' eight percent, and the Poor countries eleven percent. Sensitivity analysis on the discount rates shows they have little impact, not very surprising since country impatience is accounted for by the GDP term in Equation 4. Using different discount rates does change slightly countries' investment mixes, since the investments have different time lags associated with their returns (higher discount rates typically make physical capital investment relatively more attractive).

Each production sector has its own (well-mixed) physical capital allotment, which is increased through investment and decreased by depreciation (set at five percent a year). Physical capital created (by investment) at the end of one period is considered operational (included in the production function) in the following period. The rate of return on physical capital for each sector depends on the marginal value product of capital for that sector.

Technology enters the production functions as a constant multiplier (T in Equations 1, 2, and 3). There is a ten period lag on technology investment, i.e., the technology multiplier is *increased* based on technology investment ten periods ago, but the technology multiplier does not depreciate if investment ceases. The increase in the technology multiplier is a logarithmic function of the five-year average of technology investment (ten periods ago). The five-year moving average reflects the fact that innovation is an interactive process that takes time to bear fruit, i.e., labs must "ramp up". Using a logarithmic relationship both bounds the increase in the technology multiplier and agrees with available data. Data in Lederman (1987) shows a logarithmic relationship both between nondefense R&D spending and technology intensive exports as well as between nondefense R&D and total scientists and engineers for a number of developed countries.

A country's human capital multiple, H (in Equations 1, 2, and 3), is based on the average per student spending on education for the work force. The new H for a country is the weighted

(by population size) average of the H of the graduating class and the current H of the workforce. The H of the graduating class is based on the average per student spending (i.e., per student human capital investment) for the class over their 12 periods in school. Hence, for human capital investment both time lags and age structure are important. A one period increase in per student spending likely will have a marginal effect on the graduating class' H since it will be averaged together with the per student spending for the previous 11 periods. Also, a graduating class's H has a greater impact on the country's H as a whole when the graduating class is large relative to the work force. In addition, the "life" of a human capital investment is limited by the life expectancy of the graduating class.

Investment in the resource base increases land endowment, A (in Equation 3). This investment is analogous to exploration, but is limited by original land endowment and the sum of past additions to land endowment (via rapidly diminishing returns); thus, countries with small original land endowments but large amount of investment funds could not end up being the major resource producing country. Finally, there is a five period lag between investment in resource replenishment and increases to land endowment.

2.2.1 foreign direct investment

The three middle countries and two rich countries form a multi-national "investment corporation" that invests in and builds, when profitable, physical capital in the two poor countries. The investment corporation allocates its investment pool (the sum of contributions from the five controlling countries) in six investments (physical capital in the three economic sectors of the two poor countries) according to relative returns. The donor countries decide how much to invest in the pool based on relative returns (compared with their average return on "domestic" investments). The investment corporation has its own wage rate, rent rate, cost to produce physical capital (determined by the same function used by the individual countries), discount rate, human capital, and technology. These factors are a weighted average of the factors for the contributing countries (based on their share of the corporation's investment pool). The corporation receives rent payments (based on the rent rate of capital in the host or poor country) on their capital, which it divides among the members according to their share of the total pool. The individual countries repatriate or reinvest their shares depending on the investment-consumption rate of their home investments (determined by Equation 4).

The poor countries pay, out of their own GDP, rent on the foreign capital. They also either nationalize the foreign capital at a specified rate (set at 8 percent, a rate roughly optimal for the poor countries) or tax the investment corporation's remittances (40 percent is roughly optimal). This nationalization or tax rate influences the amount of foreign capital, beyond the obvious, by affecting the profitability of direct foreign investment since the corporation knows this rate and incorporates it into its return on investment calculation. There is also a technology transfer from the investment corporation to the poor countries. The rate of this transfer depends on the share of a sector's capital that was foreign produced and the technology's "appropriateness" (based on the ratio of human capital of the poor country to that of the investment corporation).

2.3 Environmental quality and welfare module

The environmental module essentially considers air pollution and focuses on local and regional impacts of a flow pollutant. The strategy is to relate emissions to economic activity and, to a lesser extent, economic structure and to allow countries to invest in environmental quality upgrading (or remediation). Pollution results from energy use, which is assumed to be a linear function of *production* in the resource intensive industry and a log-linear function of per capita final goods consumption. The most important aspect of this relationship is that pollution depends on consumption (which means pollution cannot be avoided completely through economic structural change). The log-linear nature of this relationship could be interpreted as consumption becoming *relatively* less polluting as countries become richer; however, in the absence of investment in environmental quality upgrading, the relationship between consumption and pollution is unambiguous, i.e., more per capita consumption leads to greater per capita pollution. This model feature captures the (often overlooked) empirical fact that primarily-consumption-driven pollution is significant in developed countries; for example, in the US, personal transport and energy use in the residential building sector account for the majority of total energy consumption and a large percentage of air pollution emissions. In addition, personal transport and personal living space have generally increased, not decreased, with wealth in developed countries.

Environmental quality and per capita final goods consumption are the arguments of a log-linear welfare function. Environmental quality is the difference between the environment in a pure state and "effective pollution," or the amount of pollution produced that is not remediated through investments in environmental quality upgrading. The exponents for goods consumption and environmental quality sum to one, and change so that the welfare weight of environmental quality increases with per capita GDP.

$$EQ = EQ_0 - P \quad (5)$$

$$P = \bar{P}(1 - \Pi) \quad (6)$$

$$W = EQ^\theta C^\phi \quad (7)$$

$$1 = \theta + \phi \quad (8)$$

$$\theta = k - dg^{GDP} \quad (9)$$

$$\Pi = 0.99(1 - f^e) \quad (10)$$

where EQ is environmental quality, EQ_0 is environmental quality in a pure state (arbitrarily set high enough so EQ is positive), P is effective pollution consumed, $\bar{P}$ is pollution produced, Π is the percentage remediated, W is welfare, C is per capita final goods consumption, GDP is per capita GDP, and k , d , and g are positives constants (all less than 1.0 and $k > dg$) that set bounds for the welfare weight on environmental quality. The percentage remediated is based on the amount of investment in environmental quality upgrading per unit of pollution produced, e , and the ease of remediation, f (currently set to 0.05). We are assuming that the maximum amount remediated is 99 percent of pollution produced and that environmental quality upgrading investment is made on a yearly basis. The easiest (cheapest) measures are taken first, then the

more expensive measures. Removing the last few percentages is quite expensive. This model of rapidly increasing marginal costs of abatement is consistent with empirical data.

The idea that environmental quality upgrading investments must be made anew each period is used to greatly simplify the model. This simplification may seem counterfactual; however, even remediation technologies like scrubbers require yearly maintenance in addition to the capital investment, and many of the least expensive measures like “good housekeeping” require annual efforts. Indeed, a greater role for operating expenditures than capital ones does not contradict some of the evidence. US Bureau of the Census (1996) data shows for all industries the share of operating costs in total abatement expenditures is 71 percent for total pollution (air, water, and solid waste) and 58 percent for air pollution.

Despite the environmental module’s simplicity, it can account for some of the complexities of scale in environmental quality upgrading. Countries with large amounts of pollution are assumed to have many pollution sources; thus, a relatively large aggregate amount of pollution could be reduced with a small per unit expenditure if at each source only the easiest measures were employed. However, a country with a small amount of total pollution most likely would have fewer sources; thus, a higher per unit expenditure would be needed to achieve a similar aggregate reduction (because a larger percentage reduction is required).

Investment in environmental quality upgrading (remediation) is not really an investment, but another form of consumption. Thus, to calculate its return the extra welfare from a cleaner environment must be converted into consumption terms. First, given no environmental upgrading, the welfare level corresponding to the current consumption and environmental quality is calculated. Next, given a certain expenditure on environmental upgrading and the same consumption level, a higher welfare level is calculated. The benefit of environmental upgrading is measured as the additional goods consumption needed to raise the no-environmental upgrading-welfare level to the environmental upgrading-welfare level. Unlike the other investments, environmental quality upgrading has a one-time immediate payoff, so no discounting is required.

2.4 Population module

The mortality rates for infants (0-1), children (1-5), and the aged (approximately 60 and up) are updated every five periods according to changes in per capita GDP (negatively) and time (negatively). Fertility is adjusted at five year intervals according to infant mortality (positively affected) and human capital (negatively affected). Aging is performed based on one year cohorts, i.e., instead of one-fifth of a cohort moving to the next one, the amount of people at each age is known. The school age population consists of 6-17, and the working population consists of 18-64. Although gender differences are not overtly modeled, we assume half of each cohort is female to calculate births.

Although explicitly modeling population by the cohort method is certainly important, the econometrically derived coefficients that adjust mortality and fertility rates have little impact (of course, the individual countries' initial population parameters and the ways population feeds back into the model are very important). Changing the coefficients in the fertility and mortality rate

adjustment equations by one standard deviation (or more in some cases) from their means had a negligible impact on per capita GDP and only a small impact on total population itself. Final populations for the various countries differed by only five percent or less between the two sets of extreme settings (i.e., +/- one standard deviation), and final age structure varied hardly at all. In fact, changing model parameters that lead to more income growth in the poor countries had a much greater impact on the poor countries' populations.

2.4.1 international migration

To examine the effects of migration-induced changes in countries' populations a simple migration module was added. It is assumed that the motivation for a worker's migrating is to maximize his human capital adjusted wage. The human capital adjusted wage is the country's wage rate divided by its human capital multiple. This operation reflects the fact that lower skilled immigrants expect lower wages than the higher skilled indigenous population. In addition, migrants are assumed to come only from the 20-35-age cohort. Besides the obvious impacts of a larger and younger population, migrants affect their host countries in more subtle ways. Migrants bring with them their country's human capital multiple and fertility rates, thus affecting the host country's (through a simple weighted average).

The direction of migration is from countries with a lower human capital adjusted wage to countries with higher ones. Migrants do not return to their source countries, nor do they remit any of their wages to relatives in those countries. The destination country of the migrants is determined from a logit model. Besides the relative weighted wage, migrants are attracted to countries where there is a history of past migration from their country and their cultures are similar (as measured by a ratio of the countries' respective human capital). Migrants are discouraged from a particular host country if that country makes an effort to restrict their migration. Countries restrict migration when their population density is high (as measured by the population divided by the initial natural resource endowment) and the prospective migrants' culture is very different from their own. Migration is encouraged when a host country's retired population is large relative to its total population.

There are two "judgmental" parameters in this module that are particularly important because they help govern the total flow of people in and out of the countries. One of these parameters is the *maximum percentage of people migrating each period* (set at 0.15), i.e., given a very large difference in adjusted wages, the maximum percentage of the 20-35-age cohort a country (or our model) will "allow" to leave. The other important parameter is the *percentage of migrants remaining in the system* (set at 0.25). Because of the limited number of destination countries in our model (relative to the real world), we believed that all migrants could not be accounted for without rather extreme changes in population occurring. Thus, we allowed the model to be *open* in this one respect: only a certain percentage of migrants actually will find their way to one of the other six countries; others will simply be "lost".

3. Base Case and Sources of Growth

The basic model is one of investment and growth; hence, the two main drags on growth are the two main drags on investment. One drag is population aging, which reduces the

percentage of GDP allotted for investment. The other drag is the environment: as countries get richer their assessment of the value of a clean environment (seen through the weight of environmental quality in the welfare function) increases; yet, getting richer means creating more pollution (again through industrial production and, especially, consumption). Countries remedy this conflict by spending on environmental quality upgrading; the consequence of this spending is less money left over for GDP growth producing investments, thus the environmental drag on GDP growth.

Both of these drags can be seen in the following plot of welfare (Figure 1). In the rich countries, both GDP per capita (not shown) and welfare leveled off in the middle periods, but then rose again. Population aging and the resulting shrinkage of the investment pool, as well as an increased concentration of spending on the environment, caused the leveling off. Migration from the middle and poor countries helped to decrease the dependency ratios, and thus raise investment—this, along with lower pollution levels because of a shift to less industry production, led to the second increase.

Insert Figure 1

The constraint on growth is a drag on investment, specifically spending on environmental quality upgrading and population aging. However, investment in and of itself does not guarantee growth; rather, it is a very specific kind of investment that generates sustained growth, that is, technology investment and, to a lesser degree, human capital investment. Even with the environment and population aging drags removed, and considering we have already disallowed the possibility of resource exhaustion to constrain growth, the key to growth is technological advance, not factor accumulation. The following run removes the environment and population dynamics (including migration)—so the share of GDP going toward investment stays essentially constant (and in the rich and middle countries fairly high)—as well as foreign direct investment and technology and human capital improvements. The remaining investments, therefore, are physical capital in the three production sectors and resource base augmentation. In this run per capita GDP² initially grew, but then clearly was limited (see Figure 2), despite the fact that the investment pools grew and the labor forces did not decline. Indeed, as economic theory would suggest, in some periods no investment was made because further investment in the physical capital stock would have negative returns.

Insert Figure 2

Human capital is believed to be and is often defined (i.e., knowledge and skills) like technology does. In addition, human capital enters our production functions in a similar way as technology. To test whether human capital can drive growth in the absence of explicit technology improvements, we reintroduce human capital investment and population dynamics (although there is still no migration). Under these conditions the rich countries reached higher levels of per capita GDP than shown in Figure 2, but their GDP still fell in the later periods. The rapidly aging Middle3 reached levels of per capita GDP that were only slightly higher than in Figure 2, and, like the rich countries, ultimately experienced a fall in GDP. In the aging countries (the rich

² We show per capita GDP instead of welfare since pollution was not modeled in this run, thus there is effectively no difference between the two measures.

countries and Middle3), the increase in human capital could not sustain growth because it had to offset the decline in the labor force, and their aging populations led their investment pools to fall toward zero. The poor countries experienced no growth—in fact they had a slight decline in per capita GDP, as well as human capital. This last result suggests that when investment is constrained, the high population growth in these countries is detrimental to per capita GDP growth. Both Middle1 and Middle2 reached higher levels of per capita GDP, and these levels are growing; however, they too will eventually experience GDP decline when their populations ultimately level and then fall. Thus, although in principle both human capital and technological improvements are the sources of sustained economic growth, as long as human capital is tied to population dynamics, its contribution to sustained economic growth will be constrained by the same limits imposed by population.

4. Impact of Global Flows on Countries with Different Starting Points

4.1 Trade

There are two obvious sources of advantage concerning trade in our system: (i) access to cheaper natural resources, and thus, lower production costs of the two final goods; and (ii) the opportunity to buy final goods at lower prices than if a country had to produce all its own consumption by importing and exporting according to that country's relative cost advantages in the various production sectors. Accordingly, we would expect a benefit from trade for countries with low resource endowments and countries with high resource endowments but low technology and human capital (which mean high costs to produce the final goods). Indeed, we find that countries always benefit from trade when they trade with a country (or countries) that has (or have) a greater resource endowment. Thus, the two rich countries and the Middle1 country are major beneficiaries of trade. In general, the poor countries also benefit from trade since they have substantial export potential in the natural resource and often (if not always) produce the final goods at higher costs.

In addition, no country ever does well if it protects one of the final goods sectors. Such protection, predictably, always results in lower purchasing power. If a country protects the good it is relatively worse at producing (i.e., produces at a higher cost), then consumers pay more for that good than they would under trade and the purchasing power of exporting the good that the country is relatively better at producing is muted. (The assumption is that protecting a sector means no imports or exports of that good.) If a country protects the good it is relatively better at producing, it enjoys a lower price for that good, but can no longer use exports of that good to buy (or import) the other good that the country is relatively worse at producing. The one exception to the adverse consequences of a protection strategy involves the middling resource endowed middle countries (Middle2 and Middle3) and protecting the *intermediate*, resource good—more on this below.

To consider the benefits of trade, as well as various trade regimes, we look at per capita consumption of the two final goods since improving purchasing power is the ultimate motivation for trade. But, we run the model without the environment drag since differences in trade regimes are most obvious in high growth scenarios. Also, to make comparisons between free trade and autarky most robust migration and FDI were not used in any runs.

4.1.1 poor countries and trade

In runs with an austerity program—the minimum share of GDP for investment is set at 20 percent—the smaller poor country (Poor2) eventually (after period 80 or so) enjoyed greater consumption (of both goods) under autarky—a gap that showed signs of increasing. This result turns out not to be a condemnation of free trade. Nor does the result support an “infant industry” argument for protection; indeed, the smaller poor country paid higher prices for the two final goods (than under free trade) throughout the run. The country increased productivity to the point where it could afford to buy more even at higher prices.

The counterintuitive result of Poor2 reflects the complexity of an international, endogenous growth system. For the poor countries, trade influences economic structure, which in turn influences investment mixes, which in turn influences future economic growth. The poor countries’ endowments lead them to specialize in resource extraction and, in later periods, the more labor-intensive service sector. Naturally, autarky forces the poor countries to develop a more complete economic structure.

The returns to investment in physical capital in the various sectors and resource base augmentation follow predictably from country endowments and economic structure. However, returns to human capital and technology investments—as shown previously, the two most important investments for long-term growth—are more complex. An improvement in technology increases the productive capacity in all sectors equally. An improvement in human capital increases the productive capacity in all sectors too, but weighted by the labor exponent in the production functions—so that the productive capacity of the service sector is increased the most, followed by the industrial sector, and then the extraction sector. The returns on investment calculations are such that the benefits to investment are clear only when there is production in a sector. Thus, when countries specialize (and particularly, when they do so in the extraction sector), the eventual benefits of an increase in technology or human capital are not appreciated in sectors (industry or service) where production is currently zero or very low. The national investor’s, arguably, shortsightedness primarily affects countries that are highly specialized or the poor countries under free trade.

Thus, under autarky, Poor2 had production in all three sectors; the benefits of increased production caused by investment in human capital and technology were evident for all three sectors, and the country invested a higher share of its investment pool in human capital and technology. Also, under autarky the final goods had higher prices, further increasing the returns to more production, and thus investments in human capital and technology. Whereas under free trade, Poor2 channeled relatively more investment toward physical capital in extraction and resource base augmentation. The higher investment by Poor2 in human capital and technology under autarky eventually led to greater human capital and technology levels that in-turn led to a larger investment pool, still further increases in human capital and technology, and ultimately enough growth to compensate for the higher final goods prices. By around the 70th period, Poor2 had a larger investment pool under autarky, and near this same time began to have considerably more investment in human capital and technology. Poor2 had an increasingly greater human capital under autarky by the 70th period, and autarky overtook free trade in technology level by

the 100th period. In the 84th period, Poor2 begins to have more consumption under autarky, and like the gap in endowments, this difference continued to grow.

The larger poor country, Poor1, produced enough in the service sector early on under free trade, that the bias against technology and human capital investment brought on by specialization did not cause its investment mix to differ that much from what it was under autarky. Indeed, it had a similar investment pool and human capital and technology level under both regimes. In fact, under free trade Poor1 was only a marginal resource base exporter by the end of the run. Poor1 benefited from free trade through lower final goods prices.

Countries of course can extract themselves from the free trade induced economic specialization-investment trap. In one such policy, Poor2 reallocated its investment mix to correct for this bias (in this case 25 percent of investment in physical capital and resource base augmentation were redirected toward human capital and technology). Under this scenario, the country maintained a larger investment pool, higher human capital, and technology, and enjoyed greater final goods consumption under free trade than autarky. This investment policy eventually led to more physical capital investment in the final goods sectors, and thus ultimately less specialization. Hence, the poor countries do indeed benefit from free trade; however, the specialization that free trade induces in the poor countries can cause—in the absence of profound foresight—under-investment in human capital and technology. Under-investments in these areas have significant long run consequences for growth and development.

4.1.2 middle countries and trade

Middle2 and Middle3, who have natural resource endowments less than the two poor countries but greater than the others, like the poor countries, had higher final goods consumption under autarky than free trade. These two middle countries are usually net exporters of the natural resource, but not major ones. Under autarky their endowments and resulting supply and demand patterns resulted in their local resource price as well as final goods prices being lower than the corresponding world prices under free trade. The greater demand for the natural resource in the rich countries (among other things) drives up the resource price beyond what it would be if these two (middle) countries were solely responsible for the pricing of the resource. Therefore, initially we believed the better performance these middle countries had under autarky resulted from the lower prices they experienced. However, on closer scrutiny, it appears that these countries too suffer from an invest bias imposed by the free trade system. To examine these issues more closely, an experiment like the one used for the poor countries was set up, but using Middle2 only—the two countries have very similar endowments, differing substantially, only in terms of population age structure and dynamics. Thus, the model was run without the environmental drag and FDI and with Middle2's population remaining constant (while the populations of the others changed as in the base case).

Surprisingly, Middle2, with a smaller resource endowment and greater human capital and technology endowment, seemed to fall in the same pattern as Poor2 in terms of performance under autarky versus free trade. Middle2 invested a higher share of its pool in human capital and technology over the first 40-50 periods under autarky compared to free trade. Meanwhile, it invested a considerably higher share of investment in resource base augmentation and physical

capital in the extraction sector under free trade throughout the run. This difference in investment priorities meant Middle2 eventually had higher human capital, technology, GDP, investment pool, and consumption of final goods under autarky.

What is meant by a “resource curse” in this context is not that a resource endowment can actually be adverse for growth. On the contrary, all countries do better, under any trade regime, when they begin with more, rather than less, resource endowment. The “curse” refers to a bias that, for countries with relatively high resource endowments, free trade imparts against human capital and technology investment—the two investments most important for long-term growth—and toward investment in resource base augmentation and physical capital in the extraction sector, at least in the early periods. One cure for this investment bias is autarky. In other words, for countries well endowed in the natural resource, free trade means that they will not do as well as they could do, but these countries still do better with greater resource endowments.

Next we looked at what factors make countries more likely to be susceptible to this investment bias. Two obvious factors are resource base and population sizes, or alternatively, perhaps just per capita resource base. Thus, we examined the investment mix when these two are changed (but other aspects of population remain constant). In general, under autarky, when the resource base was increased (but other things were held constant), per capita measures (like GDP or consumption quantities) increased as well; however, when population increased, per capita measures fell (although total output increased). Under free trade, per capita measures increased both with increases in total population (when there is no population growth) and resource base. As population increased, per capita resource base fell, and the country under autarky began to look more like a country that would benefit from getting the natural resource elsewhere (i.e., from trade). This country had to spend a greater amount of investment on producing the natural resource, and correspondingly, the price of the resource rose. On the other hand, under free trade, as the per capita resource base declined, the country was more likely to import the resource, and appropriately spend less on resource base augmentation or physical capital in extraction. In addition, when a population is young (and unchanging), an increase in total population increases the return to human capital investment. Thus, as the per capita resource base fell, the investment mixes under autarky and free trade converged.

On the other hand, when the resource endowment was increased, resource base per capita increased, and the investment mixes and long-run per capita indicators between autarky and free trade diverged. Under autarky, as the resource base *increased*, more investment can be channeled *away* from extraction motivated investments since there is no reason to extract more than is needed by the two final goods sectors. In addition, a higher natural endowment means lower levels of other factors are required to extract the same amount. However, a higher resource base per capita under free trade tends to encourage the exportation of the natural resource, and thus, extraction motivated investments (at the expense, at least in the early periods, of investments like human capital).

In addition to per capita resource base, initial human capital and technology levels were very important in the difference between free trade and autarky. Indeed, when Middle2’s initial human capital and technology was set at the starting level for the rich countries (i.e., changed from 2 to 3), free trade out performed autarky at a much lower population, or a much higher

resource base per capita than before. Earlier, Middle2's population had to increase to 700 (holding the resource base constant at 10) before free trade led to higher final goods consumption quantities than autarky; but with a higher starting level of human capital and technology, this occurred for free trade with a population of only 300. (Using the original base case population of 200, free trade and autarky were very close.) Under free trade, the higher starting levels of human capital and technology meant a lower share of investment went toward capital in the extraction sector, a higher share to human capital, a lower share to resource base augmentation, and a higher share for technology. Under autarky, increasing initial human capital and technology changed the investment mix much less than under free trade; however, the directions of change were typically the same.

At this point we briefly summarize why the choice of free trade versus autarky matters. First, countries benefit from access to a lower priced natural resource—and thus, have lower production costs—and factor endowments determine under which trade regime a country will experience these lower costs. Second, countries clearly benefit when they can freely import and export the final goods to achieve consumption baskets in the most efficient manner given their productive endowments. Third, an investment mix skewed toward human capital and technology investment is most likely to support long-run income growth, and for some countries achieving this mix is more likely under autarky, at least in the absence of some other correction to the investment decision. For Middle2 and Middle3, reasons one and three favor autarky while reason two favors free trade. To better understand the relative strengths of these three reasons for Middle2, that country's resulting investment mix under autarky was exogenously applied to a free trade run, and conversely, its free trade investment mix was exogenously applied to an autarky run.

Final goods consumption of the two “hybrid” runs—autarky using free trade's investment mix and free trade using autarky's investment mix—was less than that of the base autarky run but greater than the base free trade run. Typically, there was more industrial consumption under autarky with free trade's investment mix and more service consumption under free trade with autarky's investment mix. These results suggest that it is indeed both the lower prices enjoyed under autarky and the more optimal long-run investment mix that led Middle2 to do better under autarky than free trade. A trade regime that may allow Middle2 to capture the best of all three benefits outlined above would protect its resource industry, but allow it to trade freely in the two final goods. This strategy would allow the country to have access to a lower priced natural resource, but not to be limited in imports or exports of the final, consumption goods, nor to have its investment mix biased in favor of resource extraction investments at the expense of human capital and technology, a bias that free trade of the resource causes.

Final goods consumption under autarky and free trade in final goods plus natural resource protection were very close and, not surprisingly, higher than with free trade in all sectors. Industry consumption was slightly higher under autarky, while service consumption was slightly higher under (free trade with) protection. Although the prices of both final goods were lower under autarky, the difference in price was much greater for the industry good than the service good; thus, the relative industry-to-service good price (the determinant of the consumption good mix) was skewed toward service under protection and toward industry under autarky. The investment mixes for autarky and protection were similar, but resource base augmentation was

higher under autarky for the first 25 periods, as was technology investment, and extraction sector physical capital was slightly higher throughout, while human capital investment was slightly higher under protection.

It is somewhat disappointing and hard to say why the protection regime was not clearly superior to autarky for Middle2. One possibility is the benefit of a lower resource price essentially offset the benefit of final goods trade, given Middle2's very particular endowments and the endowments of the other countries in the free trade system. Of course, what could easily tip the scales toward the resource-protection strategy (and away from autarky) are the other global flows like migration and particularly foreign direct investment (FDI)—of which Middle2 becomes a major donor.

4.2 Foreign Direct Investment

There are four ways in which the poor or receiving countries may benefit from foreign direct investment (FDI). First, the poor countries receive physical capital that they may not otherwise be able to afford. This capital, of course, does not come without costs, since it will be foreign owned the poor countries will not capture all the returns to capital from the additional production made possible by the foreign physical capital investment. The poor countries will, however, get all the returns to labor that the additional production affords. Second, the poor countries could capture additional benefits from FDI by either taxing the remittances of the foreign firm, or by nationalizing the old foreign capital at a certain rate—a capital transfer. These methods of benefits capture (taxing or nationalizing) have clear limits since we assume the foreign firm understands fully the poor countries policy in this matter and will adjust the predicted returns to its investment accordingly. Third, the poor countries benefit from technology transfer. We assume that at least part of technology is embodied in new physical capital, and the primary vehicle for international transfer of technology is the FDI “firm” installing its technologically advanced physical capital in the poor countries. The poor countries overtime fully incorporate those technology improvements into their new, indigenously created physical capita. Finally, since we assume all FDI goes toward physical capital, rather than to “crowd out” domestic investment, FDI could “free-up” the domestic investor to concentrate more on the human capital and technology investments key to long-run success.

To assess the relative strengths of these FDI benefits, and to assess how managing FDI flows will impact the poor countries, the model was run with constant populations and with a “mild” version of the environment drag (i.e., the welfare weight of environmental quality increased more slowly with income and was capped at a lower number than in the base case). If there were no technology transfer, capital nationalization, taxing of remittances, then both poor countries did significantly worse—in terms of per capita GDP—with FDI than without it. However, if there were technology transfer, but no way to capture benefits more directly (i.e., no tax or capital nationalization), then both poor countries did better with FDI. These results suggest that the simple free market goal of equalizing rent rates across countries, i.e., investing in physical capital where its returns are highest, does not provide much benefit to poor countries or meaningfully help them solve their under-investment problem. Moreover, the payments to foreign capital can be greater than the benefits; thus, capturing benefits, or at least controlling foreign ownership, is important for the poor, recipient countries.

While maintaining the same technology transfer rate, the model was run using nationalization rates varying from two to 12 percent per year. In general, the lower the nationalization rate, the greater the amount of FDI, hence the greater percentage of capital stock owned by foreigners, and the higher the technology transfer and final technology level. A high nationalization rate meant much less FDI, and the poor countries owned over 90 percent of their capital stocks by the end of the run. The relationship between the nationalization rate and per capita GDP for the poor countries is essentially quadratic. For both countries, a very low nationalization rate (two percent) meant a very high share of foreign capital ownership, and was the worst run. The larger poor country did best with a relatively low rate (4 and 6 percent), and thus higher degree of technology transfer and foreign ownership. The smaller poor country did best for most of the run when the nationalization rate was high (12 percent), and thus, FDI was lower and a higher percentage of the capital stock is indigenously owned. However, less FDI means less technology transfer, and so Poor2 did best over the last 20-30 periods when there was more FDI, i.e., a lower nationalization rate (6 or 8 percent), and thus, the country finished with a higher level of technology. Poor2 had a greater divergence in per capita GDP for the various nationalization rates during the middle of the run, perhaps, reflecting the greater “vulnerability” to foreign control because of its smaller investment pool than the larger poor country. The two major ways in which the nature of FDI differed between the two poor countries is the smaller country had a disparity between the amount of FDI and its own investment, and FDI was more concentrated sectorally for the smaller poor country—at first, only in extraction and later in service and extraction; for the larger poor country, all three sectors eventually received FDI flows.

The mechanism of nationalization, or capital transfer, is important for the poor countries both because it increases their own capital stocks, and because it serves as a way to control the amount of foreign ownership of their economies. Another way the poor countries can manage FDI flows is by taxing the remittances. Again, the FDI benefits to the poor countries should have a quadratic-type relationship, while FDI flows should have a negative, linear-type relationship, with the tax rate. The major difference between the tax and nationalization regimes is that the tax regime discourages the investing countries much less, i.e., there is much more FDI under the tax regime. The investing countries are relatively rich, and thus, have a low degree of time impatience, i.e., low discount rates. Therefore, lowering the time horizon on an investment (nationalization) reduces the return to investment more than lowering the annual flow (a tax). Both poor countries did best with tax rates of 40 and 50 percent, and did significantly worse with a very low tax rate (5 percent). Again, for the smaller poor country did comparatively well with a very high tax rate (70 percent) for the first half of the run, but performed much worse with some lower rates at the end of the run, as the higher technology transfer benefits from those lower rates took effect.

For the larger poor country, there was no clear winner in the choice between the tax and nationalization regimes. Per capita GDP plots of the best tax regimes (40 and 50 percent rates) and the best nationalization regimes (4 and 6 percent rates), assuming the same rate of technology transfer, were virtually the same. However, for the smaller poor country the tax regime was preferable, and in the later periods, became significantly better. The smaller poor country had much less domestic investment, and so, the concern over balancing the benefits of foreign ownership of capital with the costs, i.e., the payments to foreign owned capital, was greater. The

tax regime is the better way to manage this problem since it encourages more investment, thus leading to a larger technology transfer benefit, and, by definition, regulates the payments foreign owners receive. On the other hand, the nationalization regime leads to a lower *share* of capital being foreign owned, but does not otherwise control the stream of payments those owners receive.

The last way the recipient countries may benefit from FDI involves how FDI changes their domestic investment mixes. The FDI flows are applied only to physical capital increases; thus, such flows may “free-up” domestic investment for the more long-run beneficial human capital and technology investment. Earlier we explained how free trade (versus autarky) biased the investment mixes of the poor countries toward physical capital in extraction and resource base augmentation, and away from human capital and technology. The result of this “redirection” of the investment mix was that under some circumstances the poor countries ultimately enjoyed higher consumption of final goods under autarky than under free trade, despite always facing higher prices.

To examine further the impact of FDI on the poor countries investment mixes, we compare the best FDI policies of the poor countries (technology transfer with (i) 40 percent tax and (ii) an 8 percent nationalization rate for Poor1; and technology transfer with a 40 percent tax for Poor2) with the free trade and autarky runs discussed earlier. For the larger poor country, the FDI runs had the highest by far share of investment in human capital, and the highest share in technology for the first 60 periods (after which the runs were all about the same). The FDI runs were in-between the free trade (the highest) and the autarky (the lowest) runs in extraction capital. For resource base augmentation, the FDI runs were the highest for the first half of the run, and then very low—like the autarky run.

For the smaller poor country, the results were essentially the same: FDI had the highest share of investment in human capital and technology, and fell in-between free trade and autarky for share of investment in extraction sector physical capital and resource base augmentation. FDI does adjust the poor countries’ investment priorities toward long run economic growth, however, it appears that the technology transfer aspect of FDI is more responsible for this redirection than the “freeing-up” of domestic investment resources aspect.

4.3 Migration

4.3.1 (in-)migration and rich countries

As destination countries only, migration provides a clear, substantial benefit to the rich countries whose indigenous populations are aging rapidly. Migration increases the work force directly and lowers aged dependency burdens both directly (the migrants themselves are between 20-35) and indirectly, since migrants tend to come from countries with higher fertility rates. Although, the migrants also come from countries with lower human capital, the rich countries do not suffer much human capital dilution since the rich countries can continue to increase their indigenous human capital through the increased investment pool the larger, younger population affords them. In addition, the rich countries also receive migrants from the growing, middle countries who too have high human capital. Without migration, aged dependency burdens reach 0.4 by the 80th period, and the share of GDP going toward investment drops to (or very near)

zero. With migration, aged dependency burdens fluctuate between 0.3 and 0.25, and the share of GDP for investment fluctuates between 10 and 15 percent. As a result of these higher numbers, the total investment pool actually increases in the later periods (after a decline in the middle periods). Migration is a particularly important benefit to the rich countries when the environment is considered. Welfare levels are only slightly lower under migration during the first 50 periods of the run; in the later periods, after a brief plateau, welfare continues to rise under migration, whereas without migration welfare falls in the later periods. This divergence in the last third of the run results in final welfare levels that are two to three times higher with migration than without.

4.3.2 (out-)migration and poor countries

The poor countries are typically source countries for migrants (although there is migration to the more successful of the poor countries from the other one). The move clearly benefits the migrants themselves; however, benefits to source countries are limited since we do not allow for migrants to return to their original countries, and we do not model migrant remittances back to those countries. In general, out-migration will only help the poor countries in lowering the number of mouths—a potential benefit since the poor countries begin the run with high population growth, but with low to no GDP growth. Yet, the potential cost of migration is that the very mouths that leave are in the working age, and so potentially productive. Thus, out-migration is likely to be only a short-term solution to the “too much population” problem of the poor countries, and is likely to be successful only when the workers who stay become more productive, i.e., when there is investment.

A simple migration experiment was designed: the model was run under three different scenarios in which the poor countries experienced greater (but to varying degrees) per capita GDP growth. Those scenarios involved implementing, one at a time, three different policies: (i) austerity (or forced, minimal 20 percent investment of GDP); (ii) direct foreign investment; and (iii) population/birth control (which lowered the TFR to 2.1 in 20 periods, and began after 25 periods). For comparison, a “reference case” was run without any of these three policies. Different maximum migration rates for the target population were tried for all four of these scenarios (the three policies and the reference case). In addition, all the runs assumed no migration between the two poor countries (i.e., no in-, only out-migration), and the “mild” version of the environment drag was used.

In general, migration affects the two poor countries differently because of their population sizes (their age-structures and growth rates are the same). Also, migration has somewhat different impacts on runs where investment is explicitly increased (i.e., through either austerity or FDI). For Poor1, the larger of the two poor countries, under FDI or austerity no migration was a little better—particularly at the end of the run. However, in the reference case or the population control scenario, no migration was definitely better; indeed, migration was a disaster in the reference case (see Figure 3-a below). For Poor2, no migration was somewhat better for most of the reference case run; when investment was increased through explicit means, migration was slightly better, but under the population control scenario, migration led to substantially greater per capita GDP over the second half of the run (see Figure 3-b).

Insert Figures 3 (a)-(b)

In the reference case the poor countries experienced little to no per capita growth for the first 40-60 periods; thus, when migration was allowed, there was a significant amount of migration—indeed, less than half their populations ended up being working-aged. This lowering of the working-aged population, expectedly, did nothing to spur economic growth. For Poor1, migration under these conditions clearly caused a downward spiral in all but the lowest migration scenario, and income growth in this scenario was significantly less than with no migration. For Poor2, no migration also was best (except for between periods 15-35 where high migration was slightly better). However, unlike Poor1, migration did not lead to doom, and in fact, Poor2 did significantly better under the higher migration scenarios (15 and 20 percent maximum) than it did under the lower migration ones (10 and 5 percent maximum).

The per capita GDP traces for runs with population control showed that the poor countries do benefit from lowering their populations—although lowering indigenous fertility is probably a better mechanism than out-migration. However, the basic story is similar to that above: Poor1 did increasingly better when migration was lowered (although it enjoys growth in all scenarios this time), and Poor2 did increasingly better when migration was higher. Population control coupled with migration resulted in very small populations for both countries, but each still had over half its population in the labor force.

The main reason for this asymmetry between the poor countries is that the two have the same absolute resource endowment, and so Poor2 has substantially greater natural resource endowment per capita. When the two had small, declining populations, they specialized exclusively in resource extraction, which does not require much labor to produce—unlike the service industry, which the two countries did produce under scenarios of both population and per capita growth. Thus, for Poor2 per capita growth could continue (and maybe accelerate) because when the country lost population, the denominator went down, but the numerator—solely a function of revenues from extraction—was not affected.

Under an austerity program, with one major exception, the results were quite similar for both countries. For the first 80-90 periods the countries did slightly better with lower populations (and thus higher migration); however, in the later periods the greater investment pool and thus higher levels of physical capital and technology began to pay off, and so the no migration and lowest migration scenarios did best. The one exception to this description was Poor2 under the highest migration scenario, where it clearly enjoyed the greatest levels of per capita GDP. When there was FDI the results were even more similar—both between the two countries and among the various scenarios. There was enough per capita GDP growth with FDI under all the migration conditions that there was not a great desire to migrate anyway; thus, there was little to distinguish the various runs. The basic generalizations from the other experiments did hold, but the differences were not nearly as striking as before: over much of the run (from periods 40-90), Poor1 did slightly better the less migration it had, and over the last 30 periods Poor2 did slightly better the more migration it has.

4.3.3 migration and middle countries

Not surprisingly, migration affects the middle countries differently from either the rich or poor ones. Because the middle countries are both source and destination countries for migrants, migration means for the middle countries, in part, trading their populations for the poor countries' (with those countries' lower human capital and higher fertility rates). In addition, the middle countries have significantly different indigenous population dynamics (different both among themselves and from the other two country "types" or development levels). For each of the three middle countries a series of migration policies, combining both in- and out- migration rules, were run (again, the "mild" version of the environmental drag was used). The three different in- and out- migration rules are: (i) the base case (or normal), (ii) none allowed, and (iii) restricted. For in-migration, the restricted rule means only migrants from the other middle countries are allowed (i.e., no in-migration from the poor countries). For out-migration, restricted simply refers to a lower maximum migration rate for the target population (0.06 instead of 0.15 in the base case). The possible combinations of rules results in nine different overall migration policies.

Middle1

Middle1 has the youngest and fastest growing population among the middle countries. In addition, because it is most similar to the poor countries, in terms of human capital and fertility, under the base case conditions it received significant in-migration from those countries. In any run where out-migration is limited (the "none" or "restricted" rule was used), but in-migration was not, Middle1 experienced high population growth and finished with a substantially greater population than under any other policy scenario. Under the policy of "normal" (out-migration)-"normal" (in-migration), Middle1 was very much trading part of the poor countries' populations for part of its own. Thus, it is not surprising that the worst in- and out- migration rules clearly were the "normal" ones. Because Middle1 typically achieved the lowest per capita income of the middle countries, there was little difference in population between the "none" and "restricted" in-migration rules. The "none" out-migration rule produced a slightly higher per capita GDP than the "restricted" rule throughout the run. The "none-none" (and equivalently the "none-restricted") policy led to a larger population and higher percentage of GDP for investment than the "restricted-none" (and "restricted-restricted") policy. However, the difference in per capita GDP between the "none" out-migration policy and the "restricted" one was not great. Assuming that eliminating migration is considerably more costly than controlling it, the best policy for Middle1 is probably "restricted-restricted".

Middle2

Of the five different population profiles used in the model, Middle2 enjoyed the most modest degree of population growth (i.e., change in total population) and population aging (i.e., change in aged dependency ratio). Thus, out-migration provided little "population relief" for Middle2, and not surprisingly, similar to Middle1 the "normal" rule was clearly the worst and the "none" rule the best. For the first 80 periods the "none" and "restricted" in-migration rules were very close and clearly better than "normal." However, in the last 10 periods, Middle2 began to have some negative impact from aging, and the "restricted" and "normal" rules became (close to each other and) better than the "none" rule. Thus, the best migration policy is "none-restricted". Over the short-run (the first 50 periods or so), the second best policy is "none-none," while over

the longer-run (because of some population aging) “restricted-restricted” becomes the second best.

Middle3

Middle3 has population dynamics that allow for a very high percentage of GDP for investment early on, but its population aged rapidly, causing a drop in investment even more extreme than experienced by the rich countries. As a result of its unique population dynamics, Middle3 had the most complex pattern of per capita GDP traces in response to the different migration policies. In general, policies that limited both out- and in- migration (“none-none,” “none-restricted,” “restricted-none,” and “restricted-restricted”) were the best policies over the middle periods—periods 30-60. Yet, policies that allowed for significant out- or in- migration (“normal-normal,” “normal-none,” “normal-restricted,” and “restricted-normal”) were clearly the worst over this period. Middle3 enjoyed income growth during the middle periods; however, it was still “poorer” than the rich countries, and thus, experienced some out-migration, with this loss of its workers hurting the country. At the same time, an influx from the poor countries and from the slower growing and, by now, lower human capital Middle1 put a drag on per capita growth. Because of the high degree of population aging of the indigenous population, policies that limited in-migration (“normal-none,” “normal-restricted,” “restricted-none,” and “none-none”) all led to flat per capita GDP during the last 30 periods.

Policies that allow for in-migration (“none-normal,” “restricted-normal,” “none-restricted,” “restricted-restricted,” and “normal-normal”) enjoyed sustained per capita GDP growth in the later periods. Among this second group—the “sustained-growth” policies—there was little difference in results over the last 30 periods between the “none” and “restrictive” out-migration rules (i.e., “none-normal” was very similar to “restricted-normal” and “none-restricted” was similar to “restricted-restricted”). This lack of sensitivity to the out-migration rule is not surprising since in situations of income growth people are less likely to want to migrate.

Because the “normal” in-migration rule is clearly the best in the long-run, but the “restricted” rule is much better than “normal” in the short-to-medium-run, choosing an optimal migration policy is difficult for Middle3. Among the policies that allowed for sustained per capita GDP growth, “none-restricted” was the best policy during the first 60 periods, while “none-normal” was the best over the last 30 (although the “restricted” out-migration rule resulted in only slightly lower income when keeping the in-migration rule constant). The choice between these two policies, and equivalently between these two time horizons, could be made using standard discounting.

Alternatively, Middle3 could pursue a “switch” strategy that times the change in policy from “none-none” (or “none-restricted”) to “none-normal” (or “restricted-normal”) to get as close to the envelope of maximum per capita GDP implied by the per capita GDP paths-migration policies nexus (see Figure 4 below). If the switch strategy is pursued, beginning with “none-restrictive” (rather than “none-none”) maybe best because historical patterns of migration (a proxy for social networks) are important in the destination decision of current migrants. In other words, if Middle3 allowed no migration and then switched to “normal” migration controls, they would not get the same amount of in-migration over, say, the last 30 periods, they would have

experienced if the “normal” in-migration rule was used throughout the run. Figure 4 shows Middle3’s per capita GDP for a selected group of the above policies.

Insert Figure 4

5. Conclusions

We have tried to develop a model that is “more complete” than most, i.e., a fuller treatment of population, an economic module that also considers international capital movements, and some consideration for the environment. But the most important aspects of our work in differentiating it from others, is our modeling of a diversity of “country types,” and our explicit modeling of human capital and technology investments/improvements—widely accepted as the drivers of sustained economic growth. We have allowed countries to differ in initial human capital and technology levels, and thus, in initial development or wealth levels, as well as in areas in which there is less likelihood of rapid convergence or change, i.e., natural resource endowment, population age structure, and fertility and death rates. One of the major payoffs of our approach is we find history matters. Our model has both an exogenous history, implied by our initial conditions (human capital, technology, and aspects of population that imply previous changes), as well as an endogenous history—the complex of parameter changes embedded in our simulation runs.

This paper has focused on how individual country histories or starting points impact how those countries will react or prefer to manage three types of global flows: goods (via trade), capital (via foreign direct investment), and people (via international migration). Some findings were not unforeseen; for example, in a trade model with an internationally mobile intermediate good (a natural resource in our model), country factor endowments are important in determining the benefits of free trade. Since trade changes the price that countries can buy the natural resource, it also changes countries’ cost structures of production. Another more predictable result was that aging, rich countries would enjoy economic benefits from some in-migration of more fertile populations. As countries go through rapid aging two things happen: (i) the share of GDP for investment and, accordingly, their investment pool fall (because of the link between aged dependency and the investment-consumption trade-off); and (ii) their labor force shrinks (something that can only be partially offset by increases in human capital). Migration mitigates both these problems (an increasing age dependency and shrinking labor force), both immediately and in the longer-run since migrants often have higher fertility rates than the indigenous population.

Yet, other results were much harder to anticipate, like the richness in migration policies for the middle countries, which are both source and destination countries for migrants and have individual past changes in population that imply very different profiles for the future. Also surprising was the disparity in the way the two poor countries, who have the same resource endowments, age structures, and fertility rates, were influenced by migration and foreign direct investment, primarily because their different total population sizes implied divergent prospects for economic structural diversity/specialization. A larger population (other things being roughly equal) typically results in a larger investment pool, and for investments like technology the size of the investment matters (unlike human capital, where the per capita investment is the

determining factor). In addition, for countries with relatively low human capital and wages, a larger labor endowment is needed to have a less specialized economic structure. Lastly, and perhaps most unexpected to us was that the smaller poor country would do better under autarky because free trade imparted a bias on its investment priorities that had long-run consequences, not because autarky improved the country's terms of trade. Under autarky, that country's higher investment in human capital and technology early on sowed the ground for greater per capita GDP much later in the run—a striking example of the importance of an emergent history, or path dependency in our results.

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Table 1: Initial Country Endowments

	Technology multiplier ¹	Human capital multiplier ²	Land endowment ³	Total population	TFR	Aged dependency ratio	Youth dependency ratio
Rich1	3.0	3.0	2.5	182	1.81	0.244	0.536
Rich2	3.0	3.0	10.0	300	1.81	0.244	0.536
Middle1	2.0	2.0	5.0	204	3.58	0.073	1.086
Middle2	2.0	2.0	10.0	200	2.47	0.105	0.741
Middle3	2.0	2.0	15.0	300	1.88	0.106	0.635
Poor1	1.2	1.0	20.0	465	5.96	0.071	1.392
Poor2	1.2	1.0	20.0	200	5.96	0.071	1.392

Notes: (1) The T in Equations 1-3. (2) The H in Equations 1-3. (3) The A in Equation 3.

Table 2: Production Function Exponents

	Extraction/resource replenishment	Resource intensive "industry"	Resource nonintensive "service"
Labor share	0.3	0.45	0.6
Capital share	0.7	0.20	0.3
Natural resource share		0.35	0.1

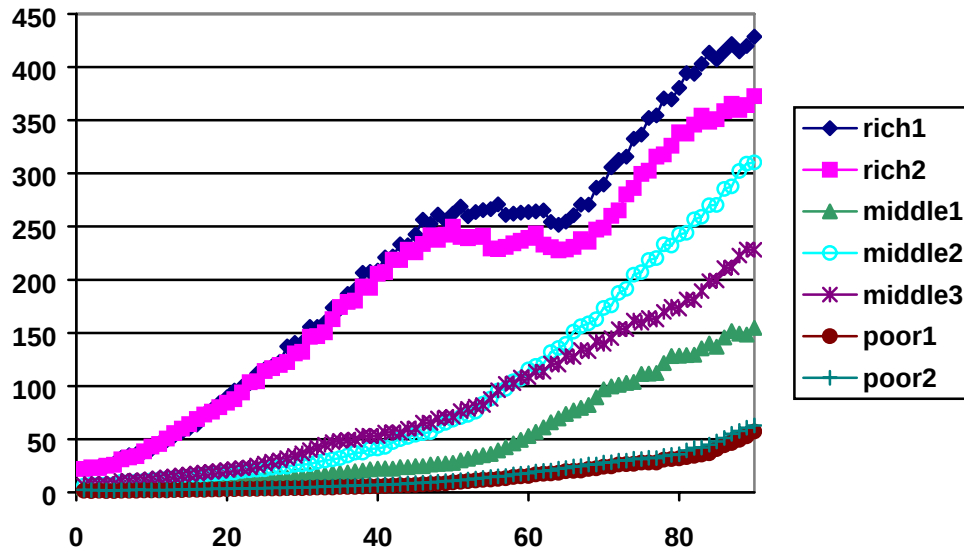


Figure 1: Welfare levels for all countries in the base case run.

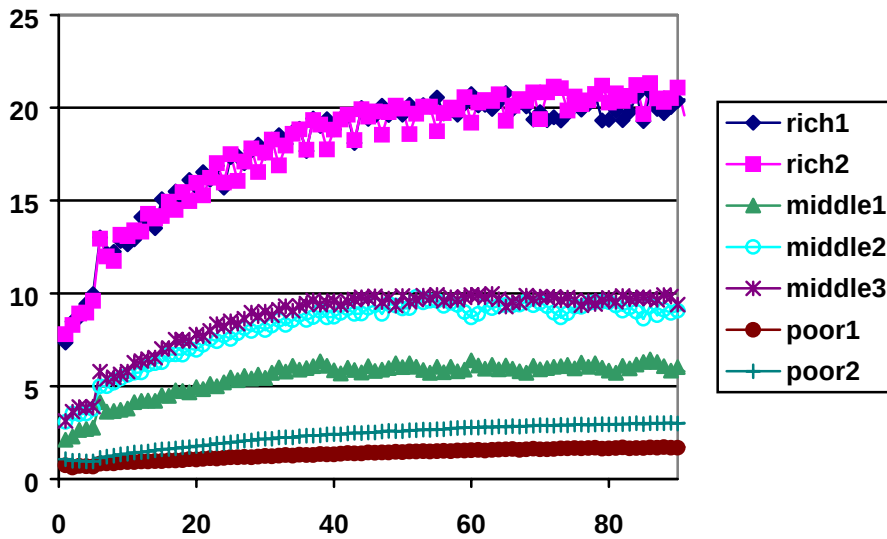
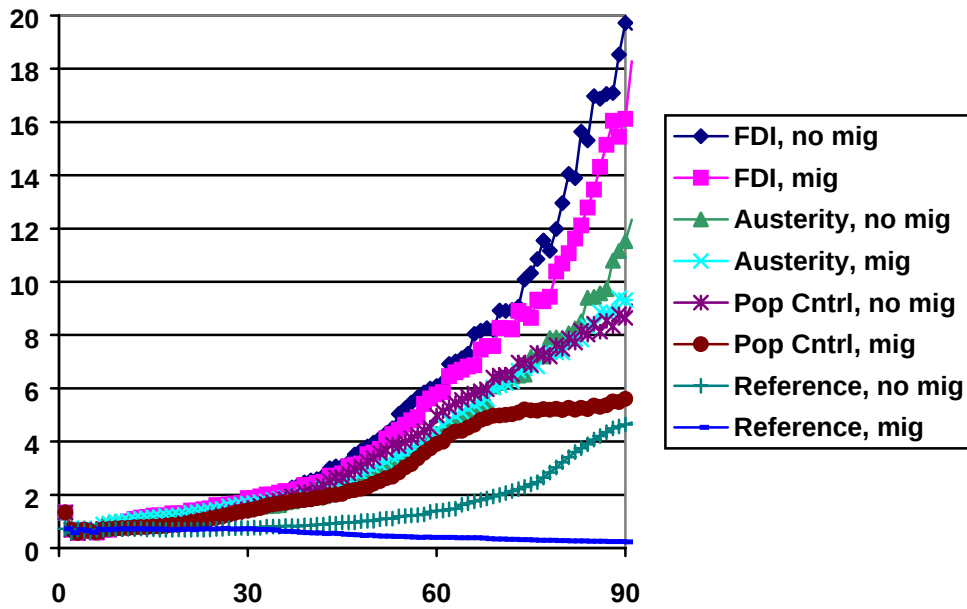


Figure 2: Per capita GDP for all countries when the base case is run without the environmental module (thus, no environmental drag), without population dynamics (thus, no population drag), without FDI, and without the ability to increase technology or human capital via investment (i.e., constant technology and human capital levels).



Figures 3 (a)-(b): Per capita GDP for Poor1 (Figure 3-a) and Poor2 (Figure 3-b) under three different growth scenarios and a reference case. The three scenarios are: foreign direct investment (“FDI”); austerity, or forced 20 percent of GDP going toward investment (“Austerity”); and population control, a policy that lowers the TFR in a specified time frame (“Pop Cntrl”). The reference case is a run with none of the above scenarios. The four cases are each run without migration (“no mig”) and with migration (“mig”). The migration parameters for these runs are set as in the base case (described in Sect. 2.4.1).

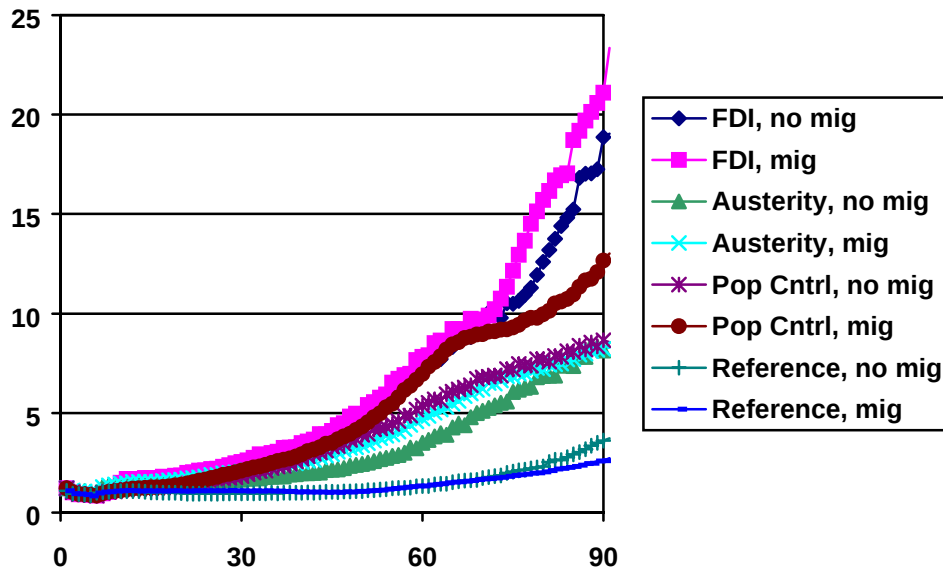


Figure 3-b: Per capita GDP for Poor2 under different growth and migration scenarios. See Figure 3-a caption for more description.

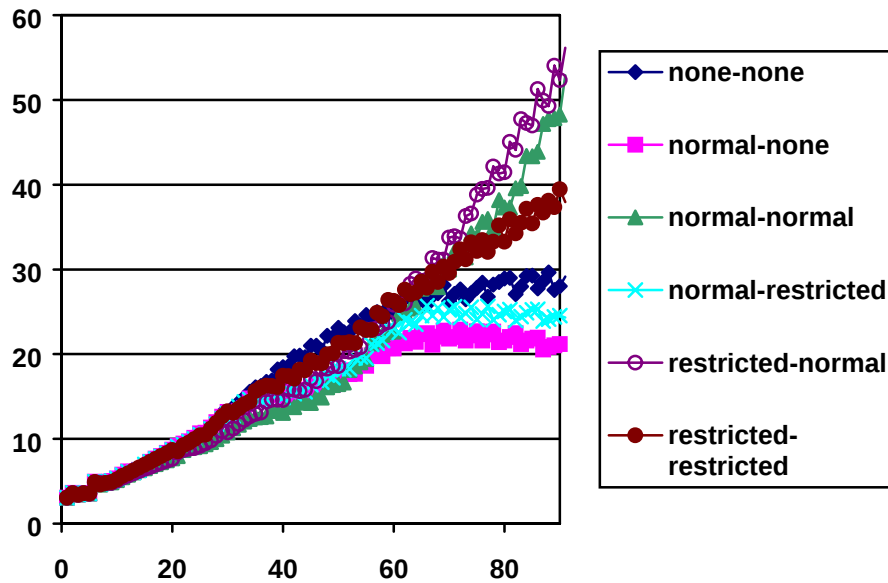


Figure 4: Per capita GDP for Middle3 under selective migration policies. The out-migration rule is designated first followed by the in-migration rule. For example, “none-none” refers to the policy that combines the “none” out-migration rule with the “none” in-migration rule. See the text (Section 4.3.3) for definitions of the three rules.