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Does a Rising Tide Lift All Boats?
Welfare Consequences of Asymmetric Growth

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Abstract: A common presumption in macroeconomics and development economics is that increased growth in the aggregate enhances welfare for everyone in the economy. I show that instead, if the underlying growth is a productivity increase in the sector consumed primarily by one group, the welfare of a second group may fall. I demonstrate this effect in two cases. In the first case, skill-biased technological change in sectors consumed by the skilled rich increases their income beyond the increase in economic wealth, causing a decline in the consumption and welfare of the low-skilled poor. This result stands in contrast to the standard model of skill-biased technological change. The second case examines trade between two countries, and demonstrates circumstances under which an increase in productivity in the nontradable sector of one country causes a welfare decline for the other country. The paper discusses evidence in support of the effects in both cases. This analysis demonstrates that a rising tide need not lift all boats and that the precise nature of consumption patterns is important for welfare.

Keywords: Welfare Inequality, Biased Technological Change, Trade Models

JEL: D60, O33, F11

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1. Introduction

Welfare is inherently difficult to measure, but evidence suggests that well-being of the poor has in fact fallen or stagnated in the face of economic growth. In the U.S., real GDP per capita increased 73% between 1970 and 2000, while the real wages of the lowest quintile earners decreased by over 20%.[1] Likewise, Brazilian GDP per capita increased over 46% during the same period, yet the living conditions of the poorest residents have not improved.[2] Thus the "rising tide" of economic growth did *not* by necessity "lift all boats", as JFK famously predicted in 1963.

Recent evidence also suggests that the "falling tide" of the recent economic crisis may have "lifted some boats". According to the World Bank Development Research Group, in 2008 (the year of the global financial crisis) the number and share of the population living on less than $1.25 a day fell in every part of the world for the first time on record. Preliminary estimates from 2010 suggest the decline has continued.[3] Similarly, data from the Gallup World Poll show that 132 million people became more food secure between between 2005 and 2008.[4] This evidence is seemingly difficult to reconcile with the fact that global output fell so substantially in 2008.

Indeed, an implicit assumption of standard economic models is that economic growth increases the welfare of everyone in the economy, even if growth is accompanied by increases in inequality. My analysis formally demonstrates circumstances under which growth actually lowers welfare for some. This paper examines two cases in which "rising tides" lead to "falling boats": First, sector-biased, skill-biased technological change in a closed economy, and second, service-sector productivity growth in a two-country model of international trade. In each case, a productivity increase complements labor supplied by a subset of people, and is biased toward the good consumed by that subset of people. As a result, the income of that subset rises more than the increase in aggregate economic wealth, causing a redistribution of productive resources away from goods consumed by others in the economy.

[1] More direct measures of welfare have also demonstrated stagnating well-being for America's poor during times of economic growth. For example, the United States Department of Agriculture documents that food security rates did not improve between 1995 (when they started reporting data) and the mid-2000s.
[2] According to the World Bank Development Research Group, in 2000, over 10% of the population continued to live on less than $1.25 a day.
[3] See *The Economist*, March 3rd-12th 2012, p. 81.
[4] See Headey (2012).

The analysis differs from earlier studies that have examined circumstances in which economic growth may reduce welfare. Examples include models of the Dutch Disease, as discussed in Corden and Neary (1982) and Krugman (1987), and of Immiserising Growth (see Baghwati 1958). Both Dutch Disease and Immiserising Growth rely on specific conditions that need not hold in general. In contrast, the explanation I provide in this paper focuses on alternative conditions that apply to labor markets in a closed economy and to a two-country international trade setting. Furthermore, the models presented below directly address the "trickle down phenomenon" often heard in policy debates.

The first part of this paper examines the effects of skill-biased technological change in a closed economy. There is a growing consensus that new technologies complement skill, either directly or through productivity growth in the production of skill-complementing capital. Existing models of skill-biased technological change and capital-skill complementarity offer explanations for the rising skill premium in the latter half of the twentieth century and predict that wage inequality is likely to continue to increase. The analysis below expands these models to incorporate an additional insight, that new technologies appear to be directed not only toward factors of production (skilled labor), but also toward goods consumed predominantly by the rich. The result of this asymmetric growth is a fall in the welfare of the low-skilled poor in addition to rising wage inequality. This finding is in contrast with the implications of the canonical one-sector model of skill-biased technological change, in which welfare increases despite rising wage inequality.[5]

An extensive literature has documented the failure of U.S. economic growth to "trickle down" to the lowest quintile of wage earners. Beaudry and Green (2003), for example, propose a model of organizational change that can generate falling real wages. However, their model relies on a counterfactual increase in the price of capital.[6] In contrast to the model in Beaudry and Green, the welfare implications of the model presented below do not rely on any assumptions about the existence or price of capital. Furthermore, the proposed model with sector-specific, skill-biased technological change is consistent with several features of the macroeconomy during the last half of the Twentieth Century, including 1) increasing expenditure

[5] See Acemoglu (1998, 2003)

[6] Similarly, in Caselli (1999), new machines that complement skilled workers replace old machines that complement unskilled workers. See Acemoglu (2002) for a survey.

shares of high-end services, 2) an increasing skill premium, 3) increasing skill intensity in high-end service sectors, and 4) a fall in the price of capital.

The proposed model of sector-specific, skill-biased technological change extends the one-sector, two-factor model in Acemoglu (1998) to an economy with two sectors producing Yachts and Potatoes and two types of agents (Rich and Poor).[7] Yachts represent goods or services consumed primarily by the Rich, while Potatoes represent goods and services consumed by the Poor. The Rich agents own an endowment of high-skilled labor, while the Poor own an endowment of low-skilled labor. The key assumptions are, first, demand for Yachts is increasing in income; second, skill-biased technological improvements are sector specific; and third, the elasticity of substitution between high skilled labor and low skilled labor is greater than unity. If technology improves in the Yacht sector, the wage of the skilled Rich increases. The Rich in turn use their increased income to demand more Yachts, which requires skilled labor to flow out of the Potato sector and into the Yacht sector. The result is a fall in the supply of Potatoes. If preferences are strongly nonhomothetic such that the Poor consume only Potatoes, their welfare will decline.

The model feature that technological growth has been biased toward the goods that the Rich consume has some empirical support in the macroeconomic literature. Buera and Kaboski (2011) document that as income has grown in the latter half of the twentieth century, there has been a substantial increase in the expenditure share of skill-intensive services such as finance, insurance, real estate, and architectural services. This evidence suggests that demand for these services depends on wealth: as wealth increases, consumers shift toward consumption of skill-intensive services ("Yachts"). Furthermore, Jorgenson and Stiroh (2000) argue that the majority of TFP growth has been in the production of computers and IT, and Bosworth and Triplett (2000) show that the most intensive users of computer technology have included high-skill services such as finance, insurance, and communications.

This supporting empirical evidence is consistent with arguments in Acemoglu (1998, 2003) that technological change responds to market forces. As the rich demand more financial services, for example, the returns to the inputs in financial service production increase, which in

[7] Appendix C extends the capital-skill complementarity model in Krusell, Ohanian, Rios-Rull, and Violante (2000), which has three factors of production, and derives the same welfare implications. This paper considers capital-skill complementarity to be consistent with skill-biased technological change and therefore refers to the two interchangeably. In contrast to Beaudry and Green (2003), the results here are consistent with a fall in the price of capital over time.

turn increases the incentive to create software for the finance industry. The implication of this form of asymmetric growth, according to the model presented below, is a bifurcation of the economy: skilled labor flows from sectors consumed by the Poor to those consumed by the Rich, depriving the Poor of goods and services.

This pattern of bifurcation is equally salient among goods or services within the same sector. Broda and Romalis (2009) document that low-income households consume a basket of goods that is entirely different from the basket of high-income individuals, even though the goods are similarly classified. Their evidence is based on scanner data for consumer goods such as Maxwell House coffee and Starbucks, but a similar pattern is likely to hold for the service sector as well. For example, low-income households use basic medical services at local clinics while the wealthy undergo plastic surgeries. If we reinterpret Yachts to be high-end services such as cosmetic plastic surgeries, the model offers insights into the implications of a plastic surgeon's office obtaining state-of-the-art operating equipment: Skilled nurses leave the clinic in the poor neighborhood to earn a higher wage at the plastic surgeon's office in the wealthy neighborhood, driving up prices or reducing quality at the clinic.

This phenomenon also is consistent with the chronic underdevelopment of the poorest neighborhoods in America, South Africa, and elsewhere. If technological improvements have been biased toward investments in products for the wealthy, skilled labor and capital will flow into the provision of goods and services for the wealthy, leaving fewer productive inputs to provide for the poor. In the poorest neighborhoods, where goods and services are consumed exclusively by the low-skilled residents, only low-quality services provided by primarily low-skilled workers will remain. Imagine a state-of-the-art auto repair shop built near a gated community in Cape Town, South Africa. Skilled mechanics will earn a high return using the new equipment, leaving the low-skilled auto workers to repair cars for the poor out of shacks in the townships. Since the low-skilled mechanics work with inferior capital equipment their marginal product remains low, as does their income. Low income implies that demand for goods and services in low-income neighborhoods remains insufficient to attract new investments that would, in turn, increase wages and wealth.

Sector-specific, skill-biased technological change is not the only source of asymmetric growth that has implications for income, demand patterns, and welfare. The second part of the paper examines welfare effects of asymmetric growth in the context of international trade between two countries. Section 4 extends the basic framework from Balassa (1964) and Samuelson (1964) to permit imperfect substitutability between two countries' tradable goods. The analysis demonstrates that productivity growth in the nontradable sector of one country may increase the price of tradables in another country, causing a fall the other country's welfare.

In the model below, country A and country B each produce a nontradable good and a tradable good that is an imperfect substitute for the other country's tradable. Productivity growth in A's nontradable sector causes a fall in welfare in B when the fall in the price of nontradables in A causes a shift in A's demand toward domestically produced tradables. This occurs whenever the elasticity of substitution between tradables and nontradables is greater than unity.[8] As the nontradable in A becomes cheaper due to increased productivity, the consumer in A substitutes toward nontradables and away from tradables. The increase in demand for A's nontradables lowers the value of tradables produced in B, causing a fall in B's terms of trade.

As in the model of sector-specific, skill-biased technological change, welfare falls in the two-country model due to a reallocation of factor inputs toward a sector (the service sector in country A) that is disproportionately consumed by one group (country A). This simple mechanism has interesting implications for prices and patterns of trade. For example, if China's demand shifts toward domestically produced goods as its productivity increases, U.S. imports from China will become more expensive, causing a fall in welfare in the U.S.

The two-country model may also help explain recent trends in global poverty. As mentioned at the beginning of the Introduction, in 2008 the number and share of the population living on less than \$1.25 a day fell in every part of the world for the first time on record. Similarly, 132 million people became more food secure between between 2005 and 2008. This evidence is seemingly difficult to reconcile with the fact that global output fell so substantially in 2008. However, it is fully consistent with the model's prediction that, as demand for resources falls in rich countries, certain goods may become more accessible to the poor. In other words, a "falling tide" may have "lifted some boats".

The two-country model builds on the framework in Balassa (1964) and Samuelson (1964) in that it allows for differences in productivity between a country's service sector and its tradable

[8] This assumption on the elasticity of substitution is a sufficient condition for the welfare effects mentioned above. Alternative assumptions may cause a decline in welfare, but I focus on the case of an above-unity elasticity of substitution because this is the implicit assumption in the new trade literature that focuses on differentiated goods under monopolistic competition.

sector. Balassa and Samuelson observe that services tend to be more expensive in rich countries than in poor countries. The Balassa-Samuelson hypothesis suggests that this correlation is because rich-country productivity is higher in the tradable sector than in the nontradable sector.

While Balassa-Samuelson is concerned with persistent differences in sectoral productivity, the model below examines the effects of a *change* in productivity in a country's service sector. When service-sector productivity increases in the rich country, the price of services in that country falls, consistent with Balassa-Samuelson. There is an additional effect in the model below, which is the increase in tradable prices in the poor country. This is due to the above-unity elasticity of substitution between tradables and nontradables and the imperfect substitutability between countries' tradable goods. The assumption of an above-unity elasticity of substitution is fully consistent with q-complementarity (as defined by Hicks 1970), and therefore is also consistent with notions that the marginal utility of services should increase with an increase in consumption of consumer goods, and vice-versa.

The models below do not incorporate endogenous technology. However, in reality technological improvements are likely to respond to market forces. For example, the arguments in Acemoglu (1998, 2003) imply that, in the closed-economy model of Section 3, technology should flow to the high-end sectors as demand for these products increases. If this endogenous technology response is skill-biased, then the welfare decrease for the Poor may be persistent and self-reinforcing in the absence of countervailing forces in the economy (such as Hicks-neutral growth and technology spillovers). Similarly, in the two-country model, as demand for services within a country increases (due, for example, to nonhomothetic preferences that place more weight on services as the economy grows), technology should flow to the service sector and prices of tradables should increase for other countries that do not experience service-sector technology improvements.

The remainder of the paper proceeds as follows: Sections 2 and 3 constitute the first part of the paper and are concerned with the closed-economy model of sector-specific, skill-biased technological change. Section 2 reports the evidence that technological improvements have been biased toward goods predominantly consumed by the wealthy. Section 3 details the baseline model and illustrates the welfare effects of sector-specific skill-biased technological change. Section 4 presents the two-country model of asymmetric technological change. Section 5 concludes.

2. Macroeconomic Evidence of Sector-Biased Technological Change

A near consensus has emerged that U.S. economic growth, especially in the 1990s, has primarily been due to productivity growth in the production and the use of information technology (IT) equipment.[9] To the extent that IT use is unevenly distributed across sectors, technological progress will be asymmetric. The questions I address in this section are first, whether there has been substantial asymmetry in the use of IT equipment (and therefore economic growth), and second, whether this asymmetry is related to consumption demand patterns.

Triplett and Bosworth (2000) note that IT use has, indeed, been concentrated in a handful of industries. The 1992 capital flow tables show that five industries (financial services, wholesale trade, business services, insurance, and communications) alone accounted for over half of new purchases of computers. If the measure of IT includes communications equipment in addition to computers and peripheral equipment, the air transportation industry also is included as a primary user of IT. The pattern based on the 1997 capital flow table is remarkably similar: At a more aggregated industry level, the three primary users of computers, software, and communications equipment are information, finance and insurance, and professional and technical services.

Of the IT-intensive industries mentioned above, four can be linked to NIPA consumption categories: finance, insurance, professional services, and air transportation. The expenditure share of each of these categories has increased in the latter part of the Twentieth Century; their combined share increased by over 57% between 1970 and 2000. As Buera and Kaboski (2011) document, each of these is a relatively skill-intensive service industry, and consumption categories that experienced increasing expenditure shares are almost exclusively skill-intensive services. Other categories, such as food, clothing, and low-skill services, have fallen or stagnated as a share of personal consumption expenditures. I interpret this evidence as indicative of nonhomothetic preferences: As income rises, demand shifts toward skill-intensive services, including those that are the most intensive users of IT.[10]

In this paper I therefore interpret evidence of productivity growth in the use and production of IT capital as technological change that is biased toward goods consumed by the

[9] See Stiroh (2002), Jorgensen (2001), Jorgensen and Stiroh (2000)

[10] The fact that the services demanded by the Rich are skill-intensive is irrelevant for the substantive results presented in Section 3 when there is sector-biased, skill-biased technological change. However, the skill intensity of the consumption bundle of the Rich will be important in the model with a government sector (Section 4).

Rich. Technological change is also assumed to be skill-biased based on the overwhelming evidence in support of skill-biased technological change (including capital-skill complementarity) in the latter part of the Twentieth Century.[11] Section 3 models skill-biased technological change in the simplest form by allowing IT technology to augment skill in production functions with two factors (skilled and unskilled labor). Appendix C treats IT equipment as an additional factor in production functions in which IT capital and skill are relative complements.

3. Baseline Model

The baseline model consists of two factors (high-skilled labor H and low-skilled labor L), two agent types (Rich and Poor), and two goods (Yachts and Potatoes) in a static economy. H Rich agents each inelastically supply one unit of high-skilled labor and L Poor agents each supply a unit of low-skilled labor. Here technology is taken as exogenous, and all markets are competitive.

3.1 Consumer Preferences

Rich (R) and Poor (P) consumers have identical nonhomothetic preferences over Yachts and Potatoes of the form

$$U_i(F_i, Y_i) = \max(a \times log(F_i + b), Y_i)$$

where $i \in R, P$ and Y_i is consumption of Yachts by consumer type i. I use F_i to denote consumption of Potatoes by consumer i (P already refers to Poor agents). This form of preferences has the useful property that consumption switches from exclusively Potatoes to exclusively Yachts as wealth crosses a certain threshold determined by the scale parameters a and b.[12] It captures the fact documented in Broda and Romalis (2009) that low-income households consume a basket of goods that is entirely different from the basket of high-income individuals, even though the goods may be similarly classified. For example, the Rich consume

[11] See, for example, Bound and Johnson (1992), Autor, Levy and Murnane (2003), and Autor, Katz, and Kearney (2008)

[12] A more common form of preferences in the structural change literature takes the form $U_i(F_i, Y_i) = \begin{cases} F_i \text{ if } F_i < \bar{F} \\ \bar{F} + Y_i \text{ if } F_i > \bar{F} \end{cases}$, in which the wealthy consume both Potatoes and Yachts but only once they've satiated their demand for Potatoes. The welfare implications are robust to this form of preferences, but these preferences are analytically inconvenient.

high-quality Starbucks coffee while the Poor consume Maxwell House instant coffee. The evidence in Broda and Romalis is based primarily on scanner data and applies mainly to different brands of goods within a sector, but I make the additional assumption that the Yacht bundle includes skill-intensive service sectors that are not included in the Potato bundle, such as financial planning services and architectural services. Since the skill-intensive services have experienced the majority of technological improvements in the form of IT use, I will assume that technological growth occurs primarily in the Yacht sector (see section 3.4).

An interesting quality of the consumer preferences is that if the wealth of the Poor were to increase, they would initially consume more Maxwell House coffee and Mickey's Malt Liquor (referred to collectively as Potatoes). At some point their wealth may be high enough that they instead purchase fine wines, airline tickets, and financial services (Yachts). I assume that endowments and technologies are such that the low-skilled Poor remain low-income and thus consume only Potatoes, while the high-skilled rich consume only Yachts. We can thus rewrite preferences as

$$U_R(\cdot) = Y_R \qquad U_P(\cdot) = a \times \log(F_P + b).$$

If the Rich were handed a Potato, it would not increase their utility. This seems reasonable; wealthy households likely have little use for malt liquor since it would take up cabinet space reserved for higher quality alcoholic beverages. Similarly, if the Poor were handed a Yacht their utility would not increase. This is clearly a less palatable assumption but may be appropriate in some contexts. If the low-income poor were given a claim on architectural services they could not use it without owning a home (which they may not be able to afford). Rather than actually use the service they would exchange it for a good or service that will provide them with utility.

3.2 Production

Potatoes (F) and Yachts (Y) are competitively produced with a constant-returns-to-scale technology using high-skilled labor and low-skilled labor:

$$F = F(z_F H_F, L_F)$$

and

$$Y = Y(z_Y H_Y, L_Y)$$

where H_j and L_j are high-skilled labor and low-skilled labor employed in sector $j \in F, Y$ and z_j is the skill-augmenting technology parameter in sector j. Here I assume that production has the same constant elasticity of substitution (CES) functional form as the models in Acemoglu (1998,2003):

$$F = \left[\eta(z_F H_F)^{\frac{\sigma_F - 1}{\sigma_F}} + (1-\eta) L_F^{\frac{\sigma_F - 1}{\sigma_F}}\right]^{\frac{\sigma_F}{\sigma_F - 1}}$$

and

$$Y = \left[\mu(z_Y H_Y)^{\frac{\sigma_Y - 1}{\sigma_Y}} + (1-\mu) L_Y^{\frac{\sigma_Y - 1}{\sigma_Y}}\right]^{\frac{\sigma_Y}{\sigma_Y - 1}}.$$

Appendix B examines equilibrium effects when production functional forms are not specified, and Appendix C incorporates IT capital into a nested CES functional form similar to that used in Krusell, Ohanian, Rios-Rull, and Violante (2000).

3.3 Equilibrium and the Effects of Asymmetric Growth

In the static competitive equilibrium consumers maximize utility subject to their budget constraints; firms maximize profits, and labor markets clear. The H Rich agents' collective budget constraint is

$$Hw_H \geq F_R p_R + Y_R p_Y$$

where w_H is the wage for high-skilled labor, p_j is the price of good j, and j_R is consumption of good j by Rich agents. Since endowments and technology are such that the Rich have enough wealth to exclusively purchase Yachts, their budget constraint can be written as

$$Hw_H \geq Y p_Y.$$

Furthermore, since production is competitive and exhibits constant returns to scale, p_Y will equal the cost-minimizing bundle of inputs necessary to produce one Yacht. Thus

$$Y p_Y = H_Y w_H + L_Y w_L$$

and we can rewrite a representative Rich agent's problem as

$$\max \left[\mu(z_Y H_Y)^{\frac{\sigma_Y - 1}{\sigma_Y}} + (1-\mu) L_Y^{\frac{\sigma_Y - 1}{\sigma_Y}}\right]^{\frac{\sigma_Y}{\sigma_Y - 1}}$$

$$\text{s.t.} \quad Hw_H \geq H_Y w_H + L_Y w_L\,. \qquad (1)$$

Likewise, the representative Poor agent's problem is

$$\max \quad .5 \times \log\left(\left[\eta (z_F H_F)^{\frac{\sigma_F - 1}{\sigma_F}} + (1-\eta) L_F^{\frac{\sigma_F - 1}{\sigma_F}}\right]^{\frac{\sigma_F}{\sigma_F - 1}}\right)$$

$$\text{s.t.} \quad L w_L \geq H_F w_H + L_F w_L. \tag{2}$$

Viewing the consumers' problem as a choice over consumption of the two labor types is helpful for understanding the comparative static effects of an increase in z_Y, which in equilibrium will depend on the substitution elasticities σ_Y and σ_F. Equilibrium is fully characterized by the budget constraints (equations (1) and (2)), utility maximization by the Rich:

$$\frac{w_H}{w_L} = \frac{\mu}{1-\mu} z_Y^{\frac{\sigma_Y - 1}{\sigma_Y}} \left(\frac{L_Y}{H_Y}\right)^{\frac{1}{\sigma_Y}}, \tag{3}$$

utility maximization by the Poor:

$$\frac{w_H}{w_L} = \frac{\eta}{1-\eta} z_F^{\frac{\sigma_F - 1}{\sigma_F}} \left(\frac{L_F}{H_F}\right)^{\frac{1}{\sigma_F}}, \tag{4}$$

and market clearing:

$$L_F + L_Y = L, \tag{5}$$

$$H_F + H_Y = H. \tag{6}$$

As noted above, technological improvements have been biased toward high-end services, which are modeled here as Yachts. Therefore the object of interest is skill-biased technology in the Yacht sector, z_Y.

Proposition 1: If high-skill labor and low-skilled labor are substitutes in the production of Yachts ($\sigma_Y > 1$), then an increase in skill biased technology in the Yacht sector (z_Y) will cause a decrease in the amount of Potatoes produced and therefore a decline the welfare of the Poor. If labor types are substitutes in the production of Potatoes ($\sigma_F > 1$) the decline will be due to an outflow of high-skill labor from the Potato sector to the Yacht sector. If labor types are complements ($\sigma_F < 1$) in the production of Potatoes the decline will be due to an outflow of both inputs from the Potato sector.

Proof: See Appendix A.

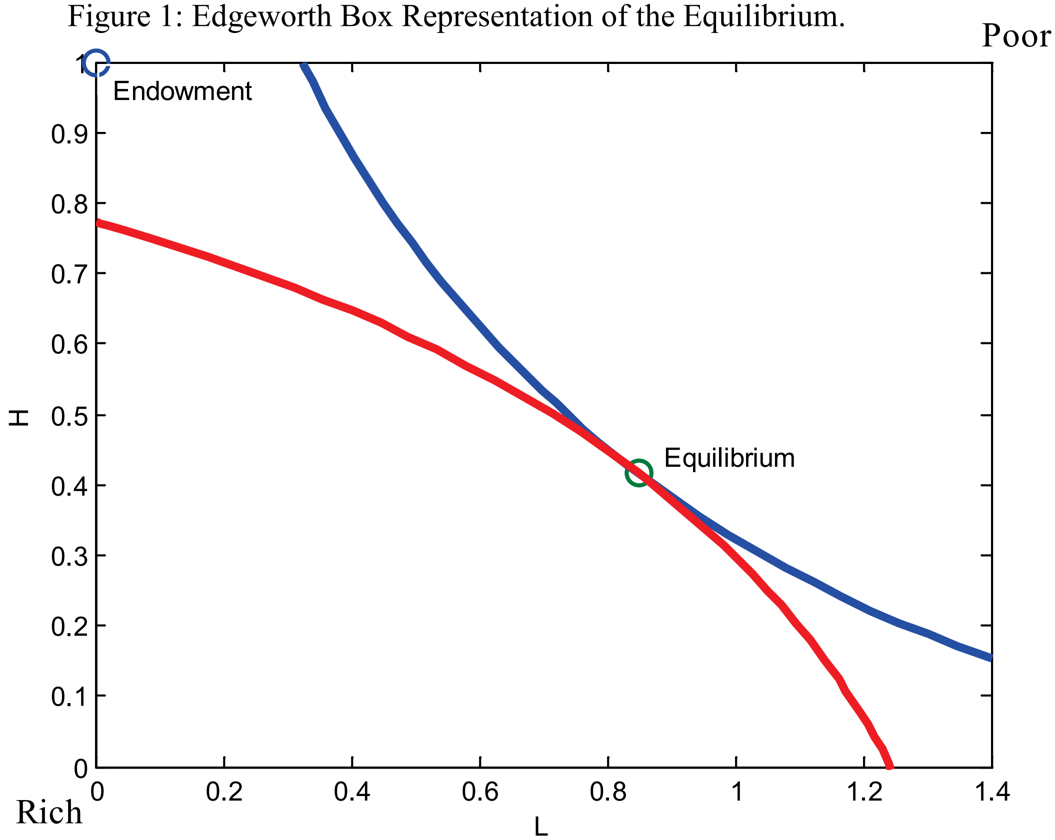
According to Katz and Murphy (1992), Angrist (1995), and Krusell, Ohanian, Rios-Rull, and Violante (2000), the empirically relevant case is when labor types are substitutes ($\sigma_Y > 1$

and $\sigma_F > 1$), although the crucial assumption for a fall in the welfare of the Poor is simply $\sigma_Y > 1$. An increase in z_Y drives up the wage premium, increasing the income of the Rich. Rich agents use their income to effectively purchase bundles of high-skill labor and low-skill labor. Since the $z_Y H_Y$ bundle is a substitute for L_Y in the Rich's utility function, the increase in z_Y increases $z_Y H_Y$, causing the Rich to desire a substitution of H_Y for L_Y. Since the increase in z_Y also increases the return to skilled labor and therefore the wealth of the Rich, the Rich are able to meet their desire for more skilled labor by purchasing skilled labor from the Poor. Skilled labor therefore flows from the Poor to the Rich (from the Potato sector to the Yacht sector).

The effect on the allocation of low-skilled labor, L, depends on the elasticity of substitution in the Potato sector. If $\sigma_F < 1$, labor types are complements for the Poor and the z_Y-induced decline in H_F lowers the value of L_F, which in turn diminishes the income of the Poor relative to the income of the Rich. In this case, the Rich have enough wealth to purchase more low-skilled labor in addition to high-skilled labor. If $\sigma_F > 1$, which is likely the empirically relevant case, the outflow of H from the Poor's consumption bundle causes a desire to substitute L for H, which increases the value of L relative to the case of complements. The Poor then are able to retain enough wealth to purchase low-skilled labor from the consumption bundle of the Rich.

When inputs are substitutes in each sector, the net effect is a fall in the utility of the Poor. This is because the effect of the outflow of high-skilled labor from the Potato sector outweighs the effect of the inflow of low-skilled labor (see Appendix A). Figures 1 through 3 illustrate the net effect of an increase in z_Y using an Edgeworth Box in which the representative agents trade high-skilled labor and low-skilled labor. Figure 1 shows the initial equilibrium. The isoutility lines are identical to isoquants in the production of Potatoes for the Poor and Yachts for the Rich. Note that the original endowment of (L, H) to the Rich is $(0,1)$. The point labeled "Equilibrium" is the point of tangency between the isoutility lines of the Rich and the Poor, and the price vector is the line (not shown) between the "Endowment" point and the "Equilbrium" point.

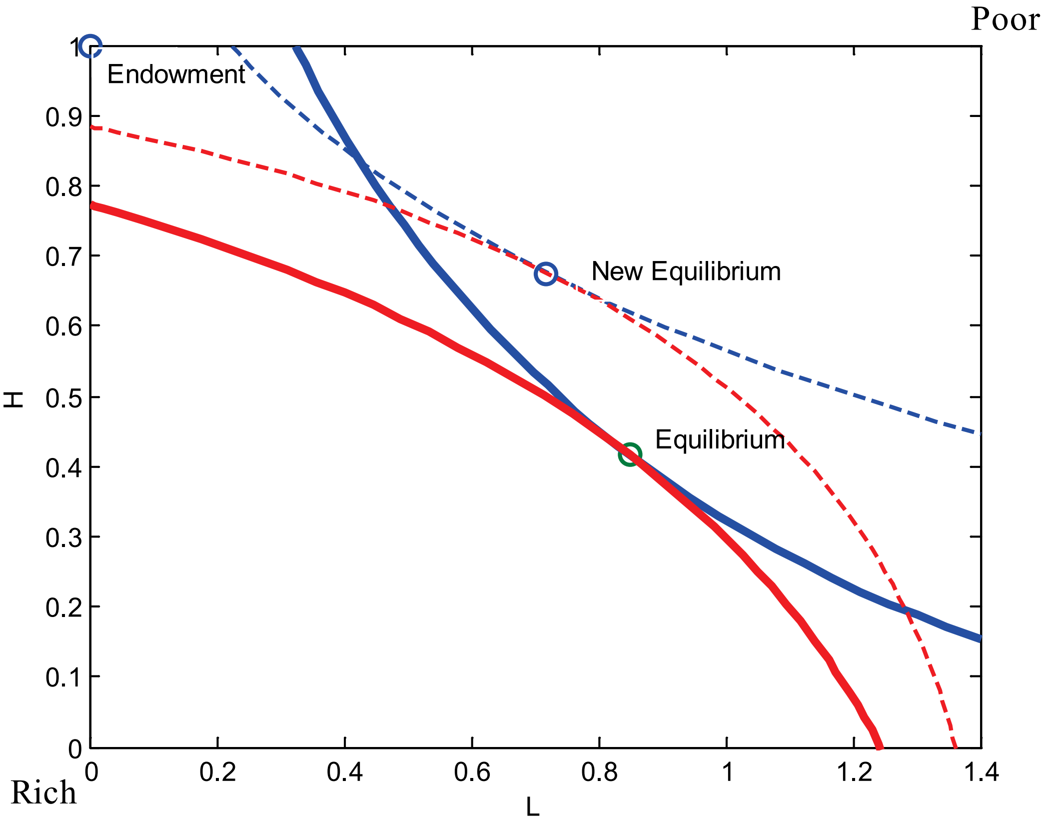
Figure 1: Edgeworth Box Representation of the Equilibrium.



Note: The ratio of H to L is the same as the skill ratio in 2000 where high-skilled labor equals hours worked by college graduates.

Figure 2 shows the effects of an increase in z_Y. The dashed lines are the new isoutility lines, and the point of tangency between the dashed lines is the new equilibrium. Note that the isoutility line of the Poor (the concave line) has shifted toward the point of zero consumption for the Poor, indicating that the utility of the Poor unambiguously falls when z_Y increases. The welfare decline of the Poor is due to the fact that z_Y complements the endowment of the Rich. The increased value of skilled labor, along with the substitution away from unskilled labor in the production of Yachts, allows the Rich to use their increased wealth to purchase additional skilled labor for the production of Yachts. Valuable skilled labor flows from Potato production to Yacht production, leaving the Poor worse off.

Figure 2: Effect of an increase in Sector-Biased, Skill-Biased Technological Change.

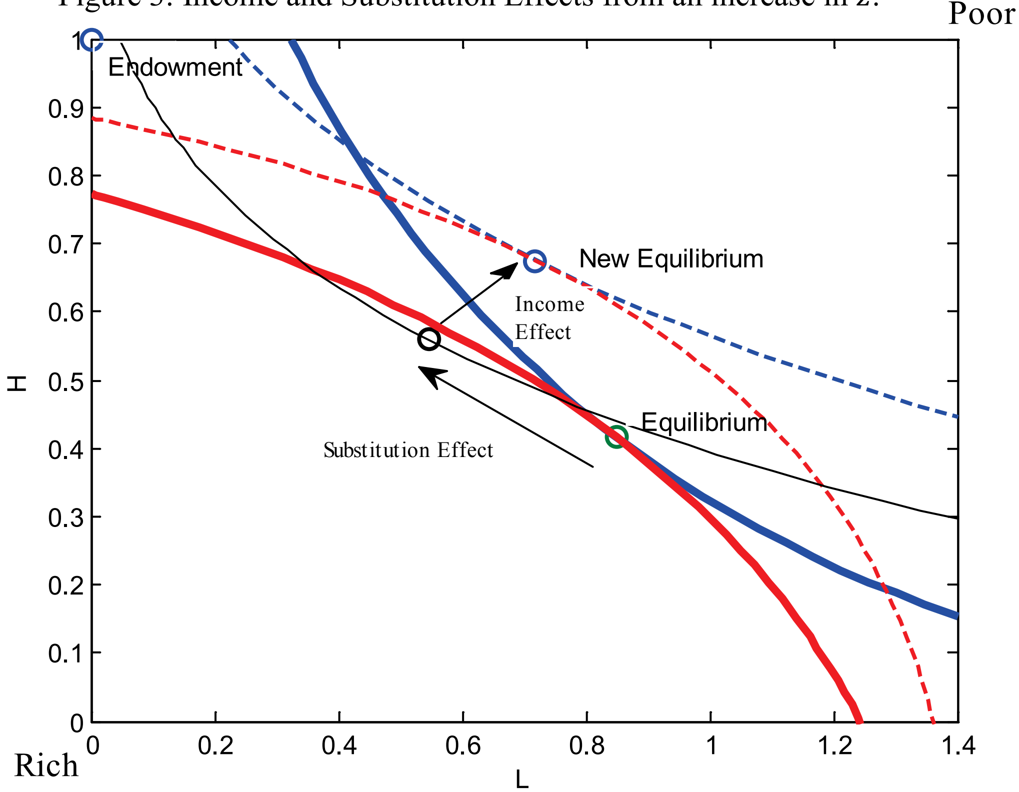


Note: The increase in z_Y is five-fold to illustrate the effects.

Figure 3 decomposes the change in allocations into what are labeled a *substitution effect* and an *income effect*. The substitution effect is defined as the change in allocations induced by an increase in z_Y when the economy's endowment point is assumed to be the original equilibrium (rather than (0,1)). The remaining distance from the original equilibrium to the actual new equilibrium is the income effect.

Figure 3 shows that the income effect, rather than the substitution effect, drives down the utility of the Poor. In fact, the substitution effect places both the Poor and the Rich on slightly higher isoutility lines (the thin solid lines). The income effect captures the fact the Rich are endowed with high-skilled labor, which has increased in value. The Rich are able to use their increased wealth to purchase additional skilled labor for the production of Yachts.

Figure 3: Income and Substitution Effects from an increase in z.



An alternative way to understand the mechanism driving down the welfare of the Poor is through prices. If we normalize the price of low-skilled labor to unity, then the price of a Potato is

$$p_F = \left[\eta^{\sigma_F}\left(\frac{w_H}{z_F}\right)^{1-\sigma_F} + (1-\eta)^{\sigma_F}\right]^{\frac{1}{1-\sigma_F}}$$

and the price of a Yacht is

$$p_Y = \left[\mu^{\sigma_Y}\left(\frac{w_H}{z_Y}\right)^{1-\sigma_Y} + (1-\mu)^{\sigma_Y}\right]^{\frac{1}{1-\sigma_Y}}.$$

When z_Y increases the marginal product of skilled labor increases, driving up w_H. The price of Yachts falls because the increase in z_Y is greater than the increase in w_H ($dw_H/dz < 1$). Potatoes, meanwhile, do not benefit from price-reducing technological change, and thus the price of Potatoes increases because of the increase in w_H. Therefore the Poor do not benefit from higher wages but must pay a higher price for their consumption good.

The Poor would benefit if technological change augments either factor in the Potato sector or augments low-skilled labor in the Yacht sector. For example, technological change biased toward low-skilled labor in the Yacht sector pulls down w_H and the price of Potatoes relative to the return on low-skilled labor, thus improving the welfare of the Poor. The Poor likewise benefit from skill-biased technological change in the Potato sector: An increase in z_F increases w_H relative to w_L, but the overall effect is a fall in the price of Potatoes.

The greater is the elasticity of substitution in the Yacht sector, the greater is the consumption loss for the Poor in response to an increase in z_Y. Define $\hat{F} = dF/F$ and $\hat{z}_Y = dz_Y/z_Y$. Then total differentiation of equations 1 through 6 yields the response of Potato production to a small change in skill-biased technology in the Yacht sector:

$$\hat{F} = -F^{-\frac{\beta}{\beta-1}} \left[\frac{\sigma_Y H_Y L(\sigma_Y - 1)(1-\eta) L_F^{-\frac{1}{\sigma_F}} L_Y}{(\sigma_F H_F + \sigma_Y H_Y)\ L_F\ (\sigma_Y - 1) + (\sigma_F L_F + \sigma_Y L_Y)(H_F + \sigma_Y H_Y)} \right] \times \hat{z}_Y,$$

the magnitude of which is increasing in σ_Y when $\sigma_Y > 1$. Most estimates of the elasticity of substitution between skilled labor and low-skilled labor are between 1.4 and 2, implying that an increase in skill-biased technology in the Yacht sector drives down the supply of Potatoes.[13] Note that the direction of the change in the supply of Potatoes does not depend on factor intensities in the two sectors.[14]

3.4 Calibration

To get a sense of the magnitude of the consumption loss for the Poor I calibrate the model by choosing $\sigma_Y = \sigma_F = 1.4$, which is at the lower end of the empirical estimates of the elasticity of substitution between skilled and low-skilled labor. I set the skill ratio, $\frac{H}{L}$, equal to 0.7, which is close to the 2000 relative supply in Buera and Kaboski (2011) and the 1996 relative supply in Acemoglu (2002). The starting values for z_Y and z_F are equal to one. Finally, I choose $\eta = \mu = 0.62$ to match the wage premium in 2000, which is approximately 2.1 (see Acemoglu and Autor 2010). With these parameter values, a percent increase in z from a starting value of 1 causes a change in the supply of Potatoes of -0.1%.

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[13] See Katz and Murphy (1992), Angrist (1995), and Krusell, Ohanian, Rios-Rull, and Violante (2000).
[14] Also note that the model is not related to the Rybcszynski Theorem, which applies to changes in the amount of a factor that is available to both sectors.

Acemoglu (2002) postulates that skill biased technology increased almost tenfold in the U.S. between 1970 and 1990, based on a one-sector model with an elasticity of substitution equal to 1.4. The model here shows that if the full extent of technological improvements had been specific to sectors exclusively consumed by wealthy college graduates, the consumption loss for low-skilled workers would have been around a magnitude of 22% in the absence of hicks-neutral technological improvements, increases in the relative supply of high-skilled labor, technology spillovers, and other sources of economic growth.

The assumption that technological improvements are confined to the Yacht sector is illustrative but not realistic. If technological improvements occur in both sectors, the net effect on the supply of Potatoes will depend on the relative magnitude of skill-biased technological change in the Yacht sector. Table 1 shows different combinations of increases in z_Y and z_F that achieve the same increase in the wage premium, along with the percent change in Potatoes per low-skilled worker. With an elasticity of substitution equal to 1.4 in both sectors, an 85% increase in z_Y requires a 13% increase in z_F to ensure that the supply of Potatoes does not fall. When the elasticity is 2, a 75% increase in z_Y will depress the Poor's consumption of Potatoes even if z_F increases by 22%. When growth is more symmetric, the consumption and welfare of the Poor improves.

Table 1: Response of Consumption of the Poor to Skill Biased Technological Improvements

$\sigma_Y = \sigma_F = 1.4$			$\sigma_Y = \sigma_F = 2$		
Increase in z_Y	Increase in z_F	Change in F	Increase in z_Y	Increase in z_F	Change in F
100%	0%	-7.0%	100%	0%	-11.0%
95%	4%	-4.8%	95%	4%	-9.1%
90%	8%	-2.6%	90%	8%	-7.3%
85%	13%	0.0%	85%	12%	-5.4%
80%	18%	2.6%	80%	17%	-3.0%
75%	24%	5.7%	75%	22%	-0.7%
70%	29%	8.3%	70%	28%	2.1%
65%	36%	11.9%	65%	34%	4.9%
60%	43%	15.4%	60%	41%	8.2%

Note: Each row generates an equivalent increase in the skill premium for a given value of the elasticity of substitution.

As in the canonical one-sector model in Acemoglu (1998), inequality increases in all cases. For example, when z_Y doubles the skill premium increases by 23.5%. Furthermore, the expenditure share of Yachts increases by over 15%. The model therefore matches both the increasing trend in the skill premium and the trend documented in Buera and Kaboski (2009) of an increasing expenditure share of high-end services over time. Finally, the model predicts that the skill intensity of the Yacht sector should increase in response to the increase in z_Y due to the inflow of skilled labor. This is exactly the pattern observed in the high-end sectors mentioned in Section 2. Between 1940 and 2000, the average skill intensity over all sectors increased almost 70%, while the average skill intensity in the high-end service sectors increased over 250%.[15]

High-end services are not the only goods consumed predominantly by the Rich. For example, the Rich may consume different auto repair and personal care services than do the Poor based on the geographic location of these services relative to where the Rich live. The model above predicts that if an auto repair shop in a Rich neighborhood experiences an increase in skill-intensive technology (or capital, as demonstrated in the Appendix), then the availability of repair services in Poor neighborhoods will fall Such a phenomenon may help explain the chronic underdevelopment of neighborhoods in South Africa during periods of aggregate economic growth, and the prevalence of retail deserts in poor American neighborhoods (see Schuetz, Kolko, and Meltzer 2012).

For a concrete example of how asymmetric growth contributes to retail deserts, consider the recent experience of North Park Hill, a poor neighborhood that is almost entirely lacking in grocery stores. In 2009, during the depths of the Great Recession, the healthy-food grocer Sunflower Markets planned to open a store in North Park Hill.[16] In 2010, during the economic recovery, Sunflower withdrew its plans for a Park Hill store and began looking for locations in wealthier communities.[17] While Sunflower executives have not explicitly stated that increasing wealth in other parts of the city (and hence higher demand) were responsible for retracting their plans for a Park Hill store, their decision to do so is consistent with the predictions of the model above. It is also consistent with the experiences of other poor American neighborhoods, many of

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[15] Based on IPUMS data used in Buera and Kaboski (2011). The high-end industries include Security and commodity brokerage and investment companies, Banking and credit, Legal services, Engineering and architectural services, Real estate, Insurance, and Air transportation.
[16] The Denver Post, March 9, 2009 Front Page http://www.denverpost.com/business/ci_11867922?source=bb
[17] The Denver Post, March 10, 2010 http://www.denverpost.com/ci_14644222

which rely on tax transfers in the form of grants to community development organizations to finance local grocery stores (see the bottom of the article cited in Footnote 16).

4. Rising Tides in International Trade

This section examines the effects of biased technological change in the form of a productivity increase in a country's service sector. As in Section 3, growth is asymmetric in the sense that the productivity increase (1) complements labor supplied by a subset of people, and (2) is exclusive to a sector consumed by that subset of people. In the case of international trade, the subset of people who benefit from the asymmetric growth is the residents of the country with an increase in its service-sector productivity.

The model below features two countries, A and B, each with a representative consumer who has utility over a nontraded service and a bundle of traded consumer goods. Each country produces a unique traded good that is an imperfect substitute for the traded good of the other country. There are no barriers to trade, and all goods are produced under perfect competition. The production technology for all goods is linear in labor, and labor is inelastically supplied in both countries.

4.1 Consumer Preferences

The utility of the representative consumer from country $j \in \{A, B\}$ is

$$U_j = \left(S_j^{\frac{\sigma-1}{\sigma}} + C_j^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{7}$$

Where S_j is the agent j's consumption of the service produced in country j. The aggregate good C_j consists of tradable goods from A and B:

$$C_j = \left[X_j^{\frac{\gamma-1}{\gamma}} + Y_j^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}},$$

where X_j is consumption in j of the tradable good produced in country A and Y_j is consumption in j of the tradable good produced in country B. The elasticity of substitution between the service and the aggregate consumer good is σ, and the elasticity of substitution between the tradable goods is γ.

The budget constraint of agent j is

$$w_j L_j = p_{Sj} S_j + p_X X_j + p_Y Y_j, \tag{8}$$

where p_{Sj} is the price of S_j, p_X is the price of the tradable good X produced in A and p_B is the price of the tradable good Y produced in country B. Market clearing for the tradable goods implies $X = X_A + X_B$ and $Y = Y_A + Y_B$.

Utility maximization subject to (8) yields optimal consumption ratios for a given set of prices:

$$\frac{Y_j}{X_j} = \left(\frac{p_X}{p_Y}\right)^{\gamma}, \qquad \frac{C_j}{S_j} = \left(\frac{p_{Sj}}{p_C}\right)^{\sigma}, \tag{8}$$

where p_C is the cost-minimizing price of the bundle C of the tradable goods:

$$p_C = \left(p_X^{1-\gamma} + p_Y^{1-\gamma}\right)^{\frac{1}{1-\gamma}}.$$

Note that both countries face the same prices p_X and p_Y for tradable goods, so the price p_C of the aggregate consumer good is also equal in both countries.

4.2 Production

The technologies in j for production of services and tradables are

$$S_A = zL_{SA}, \qquad S_B = L_{SB}, \qquad X = L_{XA}, \qquad Y = L_{YB},$$

where L_{SA} and L_{XA} are A's labor allocations to its service and tradable sectors, and L_{SB} and L_{YB} are B's labor allocations to its service and tradable sectors. Without loss of generality, labor supply is assumed to be equal to L in both countries. S_B, X, and Y are produced at unit labor cost, while S_A is produced at labor cost $1/z$. Country A's service sector is permitted to have non-unity labor productivity because the comparative static of interest is a change in z.

All sectors are perfectly competitive, so prices equal marginal costs. The wage in B is the numeraire, so that prices can be written:

$$p_{SA} = \frac{w}{z}, \qquad p_X = w, \qquad p_{SB} = 1, \qquad p_Y = 1. \tag{9}$$

where w is the wage in country A.

4.3 Equilibrium

Equilibrium consists of optimal consumption ratios in each country (8), labor market clearing in each country,

$$L = \frac{S_A}{z} + X_A + X_B, \qquad L = S_B + Y_A + Y_B, \tag{10}$$

and the trade balance condition

$$wX_B = Y_A, \tag{11}$$

where equation (11) follows from substituting the labor market clearing conditions into each country's budget constraint.

4.3 Welfare Effects of Asymmetric Growth

Proposition 2: Welfare in B is falling in z when tradable goods are imperfect substitutes and the elasticity of substitution between the nontradable and the tradable bundle, σ, is greater than unity.

Proof: Appendix D.

If the elasticity of substitution between tradables is less than unity, it is still possible for welfare to fall in B. I focus on the case of substitutability because it is consistent with the implicit assumption in the macro and trade literatures that focus on the effects of monopolistic competition.

Intuitively, the result in Proposition 2 is a result of a fall in B's terms of trade when A's service-sector productivity increases. An increase in z lowers the price of nontradable services in A. Since the elasticity of substitution between services and tradables is greater than unity, country A responds to the price decrease by demanding more services and fewer tradables. This lowers the value of tradables relative to the value of labor in A, causing A to devote labor resources to the production of services. Therefore, resources are reallocated away from provision of tradables for trade with B to the provision of nontradable services for A.

An alternative way to conceptualize the result in Proposition 2 is through price effects. The consumer price index in B can be written

$$P_B = \left(1 + (w^{1-\gamma} + 1)^{\frac{1-\sigma}{1-\gamma}}\right)^{\frac{1}{1-\sigma}}, \quad (11)$$

which is increasing in w. Therefore, if the value of labor in A increases relative to the value of labor in B, the consumer price index in B will increase and B's welfare will fall. Under the conditions stipulated in Proposition 2, the increase in z causes an increase in w because country A indirectly demands more of its labor relative to the labor of country B.

4.4 Discussion of the Two-Country Model.

The analysis in Section 4 suggests that productivity growth in any country's service sector may increase prices in other countries, reducing their welfare. This result is fairly general in that the conditions leading to this result are imperfect substitutability between traded goods and an above-unity elasticity of substitution between nontraded services and tradables. Indeed, these assumptions are implicit in most macro and trade models that incorporate monopolistic competition.

The model presented above offers a solution to what appears to be a puzzling decline in abject poverty in all parts of the world following the global economic crisis in 2008: A fall in productivity in sectors (such as financial sectors) that do not serve the world's poorest members may have freed up economic resources to provide goods and services to the poor by lowering the price of these goods and services.

One implication is that an increase in global economic activity may have adverse consequences for the poorest people in the world. An additional implication of the model is that as service-sector productivity increases in developing countries, developed countries will experience higher prices and lower welfare in the absence of other forms of economic growth.

5. Conclusion

This paper has presented two cases in which productivity gains not only fail to "trickle down" to everyone in the economy, but actually lower the welfare of a group of people. In each case, the paper presents evidence in support of the assumptions underlying the models, as well as anecdotal evidence that lend support to the models' welfare implications.

The key mechanism driving the result in the models above is an increase in the income of a subset of people that supersedes the increase in aggregate wealth in response to economic growth. This mechanism does not operate in standard models that explain rising inequality. In the canonical model of skill-biased technological change, for example, economic gains are disproportionately directed to a subset of people but nonetheless improve everyone's welfare. The primary difference between the models presented above and models of inequality is that the models presented above assume that consumption bundles not identical across the population.

In the case of sector-biased, skill-biased technological change, the difference in consumption bundles between the skilled Rich and the unskilled Poor is due to nonhomothetic preferences. The welfare decline of the low-skilled Poor is greater the more biased is growth toward high-end goods and services, or toward services in wealthy neighborhoods. The welfare loss is also greater the less important are high-end goods and services in the consumption bundle of the Poor. In the extreme, the Poor do not consume any goods that experience productivity gains, and their consumption/welfare loss is substantial.

In the case of international trade, consumption bundles differ across countries due to nontraded services, as in Balassa (1964) and Samuelson (1964). Under the assumptions that tradable goods are imperfect substitutes, and that the elasticity of substitution between services and tradables is greater than unity, the country without the service-sector productivity increase experiences a decline in its terms of trade and in its welfare.

The focus of this paper is on illustrating mechanisms that are likely to apply in a number of contexts rather than on developing methods to test these models empirically. A rigorous empirical test of the models would require matching consumption of disaggregated goods and services to the inputs used in production of the specific goods and services. Existing data clearly are inadequate for such an analysis. The development of suitable datasets for testing this proposition is beyond the scope of this paper.

An interesting avenue for empirical research would be to document productivity gains and the adoption of new technology by service establishments at the neighborhood level. If service establishments in high-income neighborhoods experience skill-biased technology improvements or utilize more high-tech capital than their counterparts in low-income areas, then the model in this paper may help explain the chronic underdevelopment of some of the poorest neighborhoods.

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Appendix A

Proof of Proposition 1: Total differentiation of equations (1) through (6) yields

$$\widehat{H_F} = -\frac{(\sigma_Y - 1)(\sigma_F L_F + L_Y)H_Y}{H_F[(\sigma_F L_F + \sigma_Y L_Y)] + H_Y[((\sigma_F + \sigma_Y - 1)L_F + \sigma_Y L_Y)]}\widehat{z_Y} \tag{A1}$$

and

$$\widehat{L_F} = \frac{(\sigma_F - 1)(\sigma_Y - 1)\sigma_Y H_Y L_Y}{(\sigma_F H_F + \sigma_Y H_Y)\ \ L_F\ (\sigma_Y - 1) + (\sigma_F L_F + \sigma_Y L_Y)(H_F + \sigma_Y H_Y)}\widehat{z_Y}, \tag{A2}$$

where $\hat{x} = dx/x$ for any variable x. Equation (A1) implies that dH_F/dz is negative if and only if $\sigma_Y > 1$. Assuming this is the case, (A2) implies that dL_F/dz is negative if and only if $\sigma_F < 1$. If we assume that the elasticity of substitution is greater than unity in both sectors, then an increase in z will cause an outflow of skilled labor from the Potato sector and an inflow of unskilled labor. We can determine the net effect on the supply of Potatoes by total differentiation of the Potato production function:

$$\frac{dF}{F}\ F^{\frac{\sigma_F}{\sigma_F - 1}} = \eta K_F^{-\frac{1}{\sigma_F}} dK_F + (1-\eta)L_F^{-\frac{1}{\sigma_F}} dL_F.$$

Substituting in (A1) and (A2) yields

$$\hat{F}\ = -F^{-\frac{\sigma_F}{\sigma_F - 1}}\left[\frac{\sigma_Y H_Y L(\sigma_Y - 1)(1-\eta)L_F^{-\frac{1}{\sigma_F}} L_Y}{(\sigma_F H_F + \sigma_Y H_Y)\ \ L_F\ (\sigma_Y\ - 1) + (\sigma_F L_F + \sigma_Y L_Y)(H_F + \sigma_Y H_Y)}\right] \times \hat{z},$$

which states that if $\sigma_Y > 1$ the supply of Potatoes decreases whenever there is an improvement in skill-biased technological change in the Yacht sector.

Appendix B

Here I alter the model in Section 3 to allow production of Yachts and Potatoes to use a general constant-returns-to-scale functional form. In the static competitive equilibrium consumers maximize utility subject to their budget constraints; firms maximize profits, and labor markets clear. The H Rich agents solve

$$\max\ \ Y_R$$

$$\text{s.t. } Hw_H = Yp_Y \tag{B1}$$

Likewise, the Poor agents solve

$$\max 1.5 \times \log(F_P + 1)$$

$$\text{s.t. } Lw_L = Fp_F \tag{B2}$$

Prices of Potatoes and Yachts are equal to unit costs c_F and c_Y:

$$c_F(w_H, w_L) = p_F \tag{B3}$$

$$c_Y\left(\frac{w_H}{z}, w_L\right) = p_Y. \tag{B4}$$

Market clearing implies

$$H_F + H_Y = H \tag{B5}$$

$$L_F + L_Y = L. \tag{B6}$$

Shepard's Lemma determines conditional factor demands in the Food sector:

$$\frac{\partial c_F}{\partial w_H} = \frac{H_F}{F} \tag{B7}$$

$$\frac{\partial c_F}{\partial w_L} = \frac{L_F}{F} \tag{B8}$$

and relative factor demands in the Yacht sector are derived setting marginal rates of technical substitution equal to the ratio of input prices:

$$\frac{\partial Y}{\partial H} / \frac{\partial Y}{\partial L} = \frac{r}{w} \tag{B9}$$

Equations A1 through A9 characterize the equilibrium. We can log-linearize the equilibrium equations to determine the effects of an increase in z on all endogenous variables:

$$\widehat{w_H} = \hat{Y} + \widehat{p_Y} \tag{B11}$$

$$\widehat{w_L} = \hat{F} + \widehat{p_F} \tag{B12}$$

$$\phi_H \widehat{w_H} + \phi_L \widehat{w_L} = \widehat{p_F} \tag{B13}$$

$$\theta_H \widehat{w_H} + \theta_L \widehat{w_L} = \theta_Z \hat{z} + \widehat{p_Y} \tag{B14}$$

$$\lambda_{H_F} \widehat{H_F} + \lambda_{H_Y} \widehat{H_Y} = 0 \tag{B15}$$

$$\lambda_{L_F} \widehat{L_F} + \lambda_{L_Y} \widehat{L_Y} = 0 \tag{B16}$$

$$\widehat{H_F} = \hat{F} + \phi_H \sigma_F (\widehat{w_L} - \widehat{w_H}) \tag{B17}$$

$$\widehat{L_F} = \hat{F} + \phi_L \sigma_F (\widehat{w_H} - \widehat{w_L}) \tag{B18}$$

$$\widehat{L_Y} - \widehat{H_Y} + (\sigma_Y - 1)\hat{z} = \sigma_Y (\widehat{w_H} - \widehat{w_L}) \tag{B19}$$

For any variable x above, $\hat{x} = \frac{dx}{x}$. I denote cost shares of labor in the Potato sector as $\phi_H \equiv w_H H_F / F p_F$ and $\phi_L \equiv w_L L_F / F p_F$. Likewise in the Yacht sector $\theta_H \equiv w_H H_Y / Y p_Y$ and $\theta_L \equiv w_L L_Y / Y p_Y$. The shares of labor types in each sector are $\lambda_{H_F} = \frac{H_F}{H}$, $\lambda_{H_Y} = \frac{H_Y}{H}$, $\lambda_{L_F} = \frac{L_F}{L}$, and $\lambda_{L_Y} = \frac{L_Y}{L}$. The elasticity of substitution between the labor types is σ_F in the Potato sector. In the Yacht sector σ_Y in the elasticity of substitution between zH and L. Solving the above system of equations yields the percentage change in Potatoes in response to a percentage increase in Yacht-specific, skill-biased technological change:

$$\hat{F} = -\frac{(\sigma_Y - 1)\lambda_{H_Y}}{\left\{(1+\sigma_F)\lambda_{H_F} + \lambda_{H_Y}\left[\frac{\sigma_Y}{\phi_H} + \frac{\lambda_{L_F}}{\lambda_{L_Y}}\left(\frac{\sigma_F \phi_L}{\phi_H} - 1\right)\right]\right\}}\hat{z}$$

Potato production will fall in response to an increase in z whenever $\sigma_Y > 1$ and $\frac{\sigma_Y}{\phi_H} + \frac{\lambda_{L_F}}{\lambda_{L_Y}}\left(\frac{\sigma_F \phi_L}{\phi_H} - 1\right) > 0$. This latter condition will hold when production functions are of the CES form as in Section 3.

Appendix C

Here I extend the model in Section 3 to include equipment capital, K. Production of Potatoes and Yachts takes the nested CES form:

$$F = \left[\eta\left(\lambda\, K_F^{\frac{\sigma_F - 1}{\sigma_F}} + (1-\lambda) H_F^{\frac{\sigma_F - 1}{\sigma_F}}\right)^{\frac{\sigma_F}{\sigma_F - 1}\frac{\beta - 1}{\beta}} + (1-\eta) L_F^{\frac{\beta - 1}{\beta}}\right]^{\frac{\beta}{\beta - 1}}$$

$$Y = \left[\mu\left(\lambda\, (zK_Y)^{\frac{\sigma_Y - 1}{\sigma_Y}} + (1-\lambda) H_Y^{\frac{\sigma_Y - 1}{\sigma_Y}}\right)^{\frac{\sigma_Y}{\sigma_Y - 1}\frac{\gamma - 1}{\gamma}} + (1-\mu) L_Y^{\frac{\gamma - 1}{\gamma}}\right]^{\frac{\gamma}{\gamma - 1}},$$

which is similar to the production function estimated by Krusell, Ohanian, Rios-Rull, and Violante (2000). The technology parameter, z, augments capital in the Yacht sector only. Alternatively, we could assume that capital is sector-specific, and that productivity improvements are unique to the production of capital used in the yacht sector. With competitive markets the effects on factor demands and prices will be the same; the only difference is that capital in the Yacht sector would be measured as zK_Y instead of K_Y. Krusell et al. implicitly assume that the unit of measurement of capital is zK (theirs is a one-sector model) in order to account for the fall in the price of equipment capital during the latter part of the Twentieth Century. However, this assumption is not necessary: in the calibrated general equilibrium model the price of K (and the price of zK_Y) can fall in response to an increase in z, as we demonstrate below.

Preferences are the same as in the baseline model, and we assume that the Rich own the economy's endowment of capital K in addition to high-skilled labor H. The representative Rich agent therefore solves

$$\max \; Y$$
$$\text{s.t.} \quad rK + w_H H \geq rK_Y + w_H H_Y + w_L L_Y \tag{C1}$$

and the Poor agent solves

$$\max \; .5 \times \log(F)$$
$$\text{s.t.} \quad w_L L \geq rK_F + w_H H_F + w_L L_F, \tag{C2}$$

where r is the price of capital.

In the competitive equilibrium the marginal rates of technical substitution must equal input prices. This consists of two equations in the Yacht sector,

$$\frac{\mu}{1-\mu} \lambda \, z^{\frac{\sigma_Y - 1}{\sigma_Y}} \left(\lambda \, (zK_Y)^{\frac{\sigma_Y - 1}{\sigma_Y}} + (1-\lambda) H_Y^{\frac{\sigma_Y - 1}{\sigma_Y}} \right)^{\frac{\gamma - \sigma}{\gamma(\sigma - 1)}} L_Y^{\frac{1}{\gamma}} K_Y^{-\frac{1}{\sigma_Y}} = \frac{r}{w_L} \tag{C3}$$

and

$$\frac{\mu}{1-\mu} \, (1-\lambda) z^{\frac{\gamma - 1}{\gamma}} \left(\lambda \, (zK_Y)^{\frac{\sigma_Y - 1}{\sigma_Y}} + (1-\lambda) H_Y^{\frac{\sigma_Y - 1}{\sigma_Y}} \right)^{\frac{\gamma - \sigma}{\gamma(\sigma - 1)}} L_Y^{\frac{1}{\gamma}} H_Y^{-\frac{1}{\sigma_Y}} = \frac{w_H}{w_L}, \tag{C4}$$

and two equations in the Food sector,

$$\frac{\eta}{1-\eta}\lambda\left(\lambda\, K_F^{\frac{\sigma_F-1}{\sigma_F}}+(1-\lambda)H_F^{\frac{\sigma_F-1}{\sigma_F}}\right)^{\frac{\beta-\sigma}{\beta(\sigma-1)}} L_F^{\frac{1}{\beta}}\, K_F^{-\frac{1}{\sigma_F}}=\frac{r}{w_L} \tag{C5}$$

and

$$\frac{\eta}{1-\eta}(1-\lambda)\left(\lambda\, K_F^{\frac{\sigma_F-1}{\sigma_F}}+(1-\lambda)H_F^{\frac{\sigma_F-1}{\sigma_F}}\right)^{\frac{\beta-\sigma}{\beta(\sigma-1)}} L_F^{\frac{1}{\beta}}\, H_F^{-\frac{1}{\sigma_F}}=\frac{w_H}{w_L}. \tag{C6}$$

Equations (C1) through (C6), in addition to market clearing conditions

$$K=K_F+K_Y,\qquad H=H_F+H_Y,\quad L=L_F+L_Y, \tag{C7-C9}$$

fully characterize the competitive equilibrium.

I calibrate the model using the parameter estimates in Krusell et al (2000):

$$\beta=\gamma=1.67,\qquad \sigma_Y=\sigma_F=0.67,\qquad \lambda=0.553,\quad \eta=0.587.$$

As in section 3, I set $\frac{H}{L}=.7$ to match its value in 2000. I set $\mu=0.65$ instead of 0.587 to help match the 2000 skill premium, $\frac{w_H}{w_L}=2.1$, and because a higher value of μ increases the relative skill intensity in the Yacht sector, consistent with the evidence in Buera and Kaboski (2009). The capital stock, $K=7$, is chosen to match the skill premium. The starting value for z is 1.

Table C1 shows the response of endogenous variables to a 10% increase in z. The supply of Potatoes, F, falls by 0.43%, due entirely to an outflow of skilled labor. Unskilled labor and capital actually flow into the Potato sector. When z increases, the technology-capital bundle zK_Y increases in the Yacht sector. Since zK_Y and H_Y are relative complements (determined by the magnitude of σ_Y relative to γ), the Rich demand more skilled labor in the Yacht sector, which increases w_H and H_Y. The Rich also demand less capital because the level of zK_Y is high relative to H_Y, which lowers the price of capital. The result is an outflow of capital from the Yacht sector and into the Potato sector. The stronger the relative complementarity between capital and skill, the stronger is the fall in r and in inflow of capital to the Potato sector. If baseline calibration is changed slightly to decrease the relative complementarity (through either an increase in σ_Y or a decrease in γ), the sign of the change in r ,K_F , or both can reverse. All other variable changes are robust to a wide range of parameter values.

Table C3: Response of Endogenous Variables to a 10% Increase in z						
$\widehat{w_H}$	$\hat{r}$	$\widehat{K_F}$	$\widehat{H_F}$	$\widehat{L_F}$	$\hat{F}$	$\hat{Y}$
1.59%	-1.70%	0.51%	-1.45%	0.29%	-0.43%	2.07%

Note: The price of low-skilled labor, w_L, is normalized to 1.

Appendix D

This section derives the result in Proposition 2 from Section 5. A sufficient statistic for welfare in B is given by the consumer price index (11). Therefore the comparative static of interest is dw/dz. If $dw/dz > 0$, then the productivity increase causes an increase in B's consumption basket and a fall in its welfare. To determine dw/dz, I first simplify some of the equilibrium conditions.

Substitute the prices (9) into the tradable demand ratios (8), to yield

$$Y_j = X_j w^{\gamma}, \tag{D1}$$

$$C_j = X_j (1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}} \tag{D2}$$

for $j = \{A, B\}$. The optimal demands of services in A and B from (8) are

$$S_A = C_A\,(w^{1-\gamma} + 1)^{\frac{\sigma}{1-\gamma}} \left(\frac{w}{z}\right)^{-\sigma}, \tag{D3}$$

$$S_B = C_B\,(w^{1-\gamma} + 1)^{\frac{\sigma}{1-\gamma}}. \tag{D4}$$

Solve the labor market clearing conditions (10) for S_A and S_B and substitute into (D3) and (D4). Also substitute (D2) for C_A and C_B:

$$z(L - X_A - X_B) = X_A (1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}} (w^{1-\gamma} + 1)^{\frac{\sigma}{1-\gamma}} \left(\frac{w}{z}\right)^{-\sigma}, \tag{D5}$$

$$L - Y_A - Y_B = X_B (1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}}\,(w^{1-\gamma} + 1)^{\frac{\sigma}{1-\gamma}}. \tag{D6}$$

Substitute the demand ratios (D1) for Y_B:

$$z(L - X_A - X_B) = X_A (1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}} (w^{1-\gamma} + 1)^{\frac{\sigma}{1-\gamma}} \left(\frac{w}{z}\right)^{-\sigma}, \tag{D7}$$

$$L - Y_A - X_B w^{\gamma} = X_B (1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}}\,(w^{1-\gamma} + 1)^{\frac{\sigma}{1-\gamma}}. \tag{D8}$$

Finally, substitute out X_B using the trade balance condition (11), and substitute out Y_A using (D1):

$$z\left(L - X_A(1 - w^{\gamma-1})\right) = X_A(1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}}(w^{1-\gamma} + 1)^{\frac{\gamma}{1-\gamma}} \left(\frac{w}{z}\right)^{-\sigma}, \qquad \text{(D9)}$$

$$L - X_A w^{\gamma}(1 - w^{\gamma-1}) = X_A w^{\gamma-1}(1 + w^{\gamma-1})^{\frac{\gamma}{\gamma-1}} (w^{1-\gamma} + 1)^{\frac{\gamma}{1-\gamma}}. \qquad \text{(D10)}$$

Equations (D9) and (D10) fully characterize the equilibrium. There are two equations and two unknowns (w and X_A). To obtain dw/dz, totally differentiate (D9) and (D10), solve for dX_A, and substitute the second totally differentiated equation into the first.[18] The total derivative is evaluated around the equilibrium for which the two countries are identical ($z = 1$). The result is

$$\frac{dw}{dz} = \frac{\sigma - 1}{2^{\frac{\sigma-1}{\gamma-1}}\gamma + \frac{3\sigma + \gamma}{2} - 1},$$

which is strictly positive whenever $\sigma > 1$ and $\gamma < \infty$.

[18] The step-by-step differentiation is available from the author upon request.