Welfare Consequences of Asymmetric Growth*

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Abstract: Standard models in macroeconomics and development economics imply that growth in the aggregate enhances welfare for everyone in the economy. I show that instead, if economic growth is biased towards the consumption bundle of the rich, the welfare of the poor may fall. I document the relevance of this mechanism during the latter part of the Twentieth Century by showing that new information technology disproportionately benefited sectors consumed by the rich.

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1. Introduction

What are the conditions under which economic growth can help or hurt the poor? An implicit assumption of standard general equilibrium models is that economic growth increases the welfare of everyone in the economy. For example, in the recent models of biased economic growth in Acemoglu (2003) and Buera and Kaboski (2012), well-being increases for everyone even when growth is accompanied by increases in inequality.

The implicit assumption in standard general equilibrium models that growth is associated with Pareto improvements for all agents in the economy is in part due to a general consensus that existing theoretical mechanisms of “immiserizing growth” are empirically irrelevant.1 Bhagwati (1958) and Johnson (1955) proposed trade models in which growth in a country’s export sector is associated with a loss in welfare when the export growth is accompanied by a sufficiently large deterioration of the terms of trade. As Krugman, Melitz, and Obstfeld (2011, p.122) note,

“Most economists now regard the concept of immiserizing growth as more a theoretical point than a real-world issue.”

While the original concept of immiserizing growth may be irrelevant in practice, understanding the consequences of growth remains a central focus in economics. Many developing countries experienced rapid growth during the latter part of the Twentieth Century, yet large portions of the population continue to live in dire poverty. In the U.S., there remains a strong public perception that living conditions failed to improve for those at the lower rungs of the economic ladder during the growth of the 1990s and 2000s (e.g. Egan 2004). Such stagnation for segments of the population, if true, is difficult to reconcile with the predictions of general equilibrium models that economic growth increases the welfare of everyone in the economy.

This paper presents a new theoretical framework to understand the conditions under which growth can reduce welfare in general equilibrium. These conditions are more general than those in the canonical models of immiserizing growth, and, as I discuss below, have been relevant in practice during the latter part of the Twentieth Century. My framework extends the standard model of skill-biased technological change (Acemoglu 1998) to distinguish between

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1 Models of Dutch disease (e.g. Corden and Neary 1982; Krugman 1987) are often considered to represent immiserizing growth. As Krugman (1987) notes, the natural resource boom associated with Dutch disease is only potentially welfare-reducing if the boom ends. Therefore Dutch disease is more akin to a temporary transfer than to a permanent increase in an economy’s production possibilities frontier.
consumption bundles of the rich and the poor, and to allow technological change to be biased toward sectors as well as toward factor inputs. When growth is biased toward the labor of a subset of the population and toward the consumption bundle of that group, the welfare of the second group may fall.

I present evidence that technological change during the latter part of the Twentieth Century was biased toward the consumption bundle of the rich, which, according to the theory, causes a fall in the welfare of the poor. 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 industries such as finance, professional services, and communications. I examine the 1997 capital flow table and derive a similar result as in Bosworth and Triplett’s (2000) analysis based on the 1992 capital flow tables. I then match the IT-intensive industries with personal consumption expenditure categories to identify the sectors which have directly benefitted from new information technology. Based on data from the Consumer Expenditure Survey, I show that the expenditure share of these IT-intensive consumer categories is strongly increasing in income.

The bias in growth toward the consumption bundle of the rich may be even larger than that implied by data on aggregate consumption categories. Recent evidence using scanner data documents that high-income individuals consume different products than do low-income individuals, even when those products are similarly classified (Broda, Leibtag, and Weinstein 2009; Handbury 2013). While data limitations prevent a mapping of IT investment to specific products, product-biased growth will amplify the extent to which growth is biased toward the consumption bundle of the Rich. For example, if financial planners have benefitted from IT technology more than payday loan establishments, then growth is even more asymmetric than is implied simply by looking at the Engel curve for an IT-intensive sector such as financial services.

I demonstrate the effect of this sector-biased growth by extending the standard model of skill-biased technological change to allow technological change to be biased toward sectors as well as toward factor inputs.2 The model features two sectors (Yachts and Potatoes) and two

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2 While the model focuses on skill-biased technological change, the same mechanism applies in the Buera and Kaboski (2012) context of skill-neutral growth that causes demand to shift toward skilled labor.
types of agents (Rich and Poor). Yachts represent goods or services consumed by the Rich, while Potatoes represent the consumption bundle of 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, skill-biased technological improvements are sector specific; and second, 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 and a decline in the welfare of the Poor.

According to the theory, the sector-biased growth of the 1990s reduced the welfare of America’s low-skilled poor. A number of other mechanisms that I do not explicitly model may have offset the effect of sector-biased growth, so the net effect on the welfare of the Poor is unclear. For example, cheaper imports due to trade liberalization and efficiency gains in the production of goods consumed by the poor may have lowered the cost of consumption and increased welfare for low-income Americans (e.g. Fajgelbaum and Khandelwal 2014). Based on changes in prices of subsets of goods consumed by the poor, as well as on changes in quantities of some amenities consumed such as in-home air conditioning, it appears that the economic conditions of America’s poorest members have improved during the end of the Twentieth Century (Broda, Leibtab, and Weinstein 2009; Meyer and Sullivan 2011). However, it remains unclear whether increased consumption of subsets of goods applies generally to the entire consumption basket of the poor. If other unexamined goods and services became more expensive or less accessible to low-income individuals, then well-being may have fallen, consistent with publicized perceptions. For example, consumer goods at Wal-Mart may have gotten cheaper, but the availability of other goods and services may have fallen (and effective prices risen) to offset any welfare benefits of lower Wal-Mart prices.

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3 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.

4 I use the terms ‘high-skilled’ and ‘low-skilled’ in accordance with the literature on skill-biased technological change. However, the model’s mechanism is relevant when technological change is biased toward any factor (e.g. capital) that is not equally owned across groups.
Below I provide suggestive evidence that welfare of the low-skilled poor may have fallen during the time of sector-biased growth. Rather than examining prices of subset of goods, I examine direct measures of well-being using measures of hardship from the Survey of Income and Program Participation (SIPP). Between the mid-1990s and mid-2000s Americans with low educational attainment became increasingly likely to report direct hardships; including hunger, inability to meet basic expenses, and lack of access to utilities. The association between economic growth and falling welfare over time also holds across regions. The fall in well-being was higher among states that experienced the highest per capita growth rates than among states with the lowest growth rates.

The evidence is suggestive of falling welfare during a time of rapid economic growth but does not specify which goods or services became more costly for low-income consumers to obtain. One possible candidate service is access to quality health care. If low-income households use basic medical services at local clinics while the wealthy consume high-end medical services, then 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. Testing this mechanism would require data on the evolution of quality of medical services and accessibility across different segments of the population. While such data is not available, suggestive evidence of this mechanism exists for other services. Shuetz, Kolko, and Meltzer (2012) document a decrease in retail employment in poor neighborhoods between the mid-1990s and mid-2000s, conditional on neighborhood characteristics. This outflow of workers is consistent with the model’s prediction that growth biased toward the consumption bundle of the rich causes a decline in the labor resources devoted to producing goods and services for the poor. Evidence from the financial industry is also consistent with the model’s predictions. Finance is an IT-intensive service consumed predominantly by the Rich and thus corresponds to Yachts in the model. According to Phillipon and Reshef (2009), the wage premium in the finance industry was 50% greater in the mid-2000s than it was at the beginning of the 1990s. Skilled labor also shifted toward the finance sector: According to Goldin and Katz (2008), the percentage of young Harvard College graduates employed in the finance industry in the mid-2000s was over three times the proportion for
coHORTS FROM PREVIOUS DECADES, CONSISTENT WITH THE MODEL’S PREDICTION THAT SKILLED LABOR REALLOCATED AWAY FROM THE CONSUMPTION BUNDLE OF THE POOR TO THAT OF THE RICH.

WHILE THE FOCUS OF THIS PAPER IS ON A CLOSED ECONOMY SETTING, THE WELFARE-REDUCING MECHANISM, A RISE IN INCOME OF A SUBGROUP THAT SUPERScedes THE INCREASE IN AGGREGATE INCOME, APPLIES IN THE CONTEXT OF INTERNATIONAL TRADE AS WELL. THE MECHANISM MAY BE ESPECIALLY RELEVANT AS EMERGING ECONOMIES SUCH AS CHINA EXPERIENCE GROWTH IN THEIR SERVICE SECTORS. A PREVIOUS DRAFT OF THIS PAPER, MURPHY (2012), ILLUSTRATES THE MECHANISM IN A TWO-COUNTRY MODEL IN WHICH GROWTH IN THE SERVICE SECTOR IN ONE COUNTRY CAUSES HIGHER PRICES FOR THAT COUNTRY’S EXPORTS, AND THUS FALLING WELFARE FOR THE OTHER COUNTRY.


THIS PAPER ALSO RELATES TO A LITERATURE DOCUMENTING THE FAILURE OF U.S. ECONOMIC GROWTH TO “TRICKLE DOWN” TO THE LOWEST QUINTEILE 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.5 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 END OF THE TWENTIETH CENTURY, INCLUDING INCREASING EXPENDITURE SHARES OF HIGH-END SERVICES, AN INCREASING SKILL PREMIUM, AND INCREASING SKILL INTENSITY IN HIGH-END SERVICE SECTORS.

5 SIMILARLY, IN CASELLI (1999), NEW MACHINES THAT COMPLEMENT SKILLED WORKERS REPLACE OLD MACHINES THAT COMPLEMENT UNSKILLED WORKERS. SEE Acemoglu (2002) FOR A SURVEY.
The remainder of the paper proceeds as follows. Section 2 presents evidence that technological change has been biased toward the consumption bundle of the rich. Section 3 develops a model to allow for sector-biased technological change, and it demonstrates the mechanisms through which this form of asymmetric growth causes a fall in the well-being of the low-skilled poor. Section 4 documents an increase in hardship among Americans with low educational attainment between the 1990s and mid-2000s, which suggests that the model’s mechanism may have offset other forces that lowered some costs for low-income consumers. Section 5 concludes.

2. Technological Change Biased toward the Consumption Bundle of the Rich
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.\(^6\) 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.

The industries that invested in new IT technology the most also tend to be inputs in sectors consumed predominantly by high-income individuals. The Bureau of Economic Analysis (BEA) provides the Input-Output commodity composition of each Personal Consumption Expenditure category, which permits a mapping between the IT-intensive industries and specific consumer products. Table 1 lists the industries that use new IT technology the most, along with

their associated consumer expenditure categories. The most IT-intensive industries that are direct inputs into consumer expenditure categories are telecommunications, professional services, credit intermediation, air transportation, and cable networks. These industries account for over 40% of total expenditure on IT investment in 1997, and are also among the most intensive users of IT as a share of value added. The corresponding consumer expenditure categories for these industries are TV, radio, legal, medical, financial, and air transportation services.

The consumption share of these IT-intensive goods is strongly increasing in income. Table 2 shows expenditure shares for different levels of the income distribution. According to column (1), the expenditure share on financial services, communications (including computers and TV and radio services), professional services, and air transportation was 15% for members in the lowest third of the income distribution, compared to 27% for individuals in the top 30% of the income distribution. Differences in expenditure shares are even more extreme for certain subsets of consumer services. Column (2) shows that high-income individuals spend nearly three times as much on financial services as a percentage of their income as do low-income individuals.

Thus the BEA input-output tables demonstrate a strong dependence of expenditure shares on IT-intensive sectors on income at the aggregate level. While data limitations prevent a mapping of IT investment to specific products, recent evidence using scanner data suggests that the bias at the product level may be larger than implied by the aggregate data. Broda, Leibtag, and Weinstein (2009) and Handbury (2013) document that high-income individuals consume different products than do low-income individuals, even when those products are similarly classified. For example, if financial planners have benefitted from IT technology more than payday loan establishments, then growth is even more asymmetric than is implied simply by looking at the Engel curve for an IT-intensive sector such as financial services.\(^7\)

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 Rich. Technological change is also assumed to be skill-biased based on the overwhelming

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\(^7\) Growth could also be biased due to its effect on product-level demand patterns, as suggested by the analysis in Buera and Kaboski (2012). If factor-neutral growth causes a shift in demand toward skill-intensive medical services (such as plastic surgery), for example, then growth is biased away from basic medical services consumed by the poor.
evidence in support of skill-biased technological change (including capital-skill complementarity) in the latter part of the Twentieth Century. 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
Section 2 documents that growth has been biased toward sectors consumed by the rich. The paper also assumes that growth has been biased toward skilled labor, consistent with Acemoglu (1998) and Buera and Kaboski (2012). This section develops a formal model to demonstrate that sufficiently biased growth causes a fall in the well-being of the low-skilled poor.

The baseline model consists of two factors (high-skilled labor \( H \) and low-skilled labor \( L \)) and two agent types (Rich and Poor) 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. Technology is exogenous, and all markets are competitive.

3.1 Consumer Preferences
Let \( x \) denote a vector of consumer goods and services, and let \( F(x) \) and \( Y(x) \) represent bundles of consumer goods and services. I refer to the \( F \) bundle as Potatoes (\( P \) already refers to Poor agents), and the \( Y \) bundle as Yachts. Rich (\( R \)) and Poor (\( P \)) consumers have identical preferences over of the form

\[
U_i(x_i) = \max\{a \times \log(F(x_i) + b), Y(x_i)\}
\]

where \( i \in \{R, P\} \). This form of preferences has the useful property that the consumption bundle switches from \( F \) to \( Y \) as wealth crosses a certain threshold determined by the scale parameters \( a \) and \( b \).

If \( F(x) \) and \( Y(x) \) are homothetic functions, then \( U \) is also homothetic when \( F = Y \). However, we will assume that the Yacht bundle places more weight on the types of goods for which high-income individuals have high expenditure shares. The difference between \( F \) and \( Y \)

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8 See, for example, Bound and Johnson (1992), Autor, Levy and Murnane (2003), and Autor, Katz, and Kearney (2008)
captures the fact documented by Broda, Leibtag, and Weinstein (2009) and Handbury (2013) that low-income households consume a basket of goods that is different from the basket of high-income individuals, even though the goods may be similarly classified. For example, the Rich consume high-quality Starbucks coffee while the Poor consume Maxwell House instant coffee.

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 goods from the Yacht bundle, such as fine wines, airline tickets, and financial services. I assume that endowments and technologies are such that the low-skilled Poor remain low-income and thus consume only the Potato bundle, while the high-skilled rich consume only the Yacht bundle. We can thus rewrite preferences as

\[ U_R(\cdot) = Y(x_R) \quad U_P(\cdot) = a \times \log(F(x_P) + b). \tag{1} \]

### 3.2 Production

Here we abstract from production of the individual elements of \( x \) and instead specify aggregate production functions of the different bundles. 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 in the models in Acemoglu (1998, 2003):

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

\[ \tag{2} \]

and

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

\[ \tag{3} \]
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
The competitive equilibrium is characterized by consumer optimization, profit maximization by firms, and factor market clearing. It is useful to reframe the model in terms of an endowment economy with preferences over the endowed factors because doing so permits an Edgeworth Box graphical representation of the model’s comparative statics. Specifying consumer preferences over factors and technology also helps illustrate the similarities between this model and that in Buera and Kaboski (2012), which explores a demand-based explanation for the rising skill premium during the latter part of the Twentieth Century. Buera and Kaboski similarly demonstrate how their model can be recast in terms of preferences over technology. In their static model, factor neutral increases in technology induce higher demand for skill-intensive services, raising the wage of skilled workers. The key difference between the model here and the model in Buera and Kaboski (2012) is that their model features ex ante identical workers who have equal consumption. In the current model, income is not shared across worker types and thus the Poor are made worse off if technology (as in the case of skill-biased technology change) or growth-generated demand shifts (as in Buera and Kaboski 2012) are sufficiently sector-and-factor biased.

First consider the optimization problem of Rich agents, which is to maximize \( Y(x) \) subject to the budget constraint

\[ Hw_H \geq F_R p_R + Y_H p_Y \]

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

\[ Hw_H \geq Y p_Y. \]  \hspace{1cm} (4)

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

\[ Y p_Y = H_Y w_H + L_Y w_L. \]  \hspace{1cm} (5)
We can substitute (5) into (4) to write the budget constraint of the Rich in terms of skilled and low-skilled labor:

\[ Hw_H \geq H_Y w_H + L_Y w_L. \]  \hspace{1cm} (6)

We can also write the utility function in terms of factor inputs by substituting the production function for \( Y \) into the Rich’s utility function in equation (1). Thus the Rich agent’s problem is equivalent to

\[
\max \left[ \mu (z_Y H_Y)^{\frac{\sigma_Y - 1}{\sigma_Y}} + (1 - \mu) L_Y^{\frac{\sigma_Y - 1}{\sigma_Y}} \right]^{\frac{\sigma_Y}{\sigma_Y - 1}} \\
\text{s.t. } Hw_H \geq H_Y w_H + L_Y w_L.
\]

Likewise, the representative Poor agent’s problem is

\[
\max .5 \times \log \left[ \eta (z_F H_F)^{\frac{\sigma_F - 1}{\sigma_F}} + (1 - \eta) L_F^{\frac{\sigma_F - 1}{\sigma_F}} \right]^{\frac{\sigma_F}{\sigma_F - 1}} \\
\text{s.t. } Lw_L \geq H_Y w_H + L_Y w_L. \hspace{1cm} (7)
\]

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 \( \sigma_Y \) and \( \sigma_F \). Equilibrium is fully characterized by the budget constraints (equations (6) and(7)), utility maximization by the Rich:

\[
\frac{w_H}{w_L} = \frac{\mu}{1 - \mu} z_Y^{\frac{1}{\sigma_Y}} \left( \frac{L_Y}{H_Y} \right)^{\frac{1}{\sigma_Y}}, \hspace{1cm} (8)
\]

utility maximization by the Poor:

\[
\frac{w_H}{w_L} = \frac{\eta}{1 - \eta} z_F^{\frac{1}{\sigma_F}} \left( \frac{L_F}{H_F} \right)^{\frac{1}{\sigma_F}}, \hspace{1cm} (9)
\]

and market clearing:

\[
L_F + L_Y = L, \hspace{1cm} (10)
\]

\[
H_F + H_Y = H. \hspace{1cm} (11)
\]

As noted above, technological improvements have been biased toward goods consumed predominantly by individuals with high incomes. Therefore the object of interest is skill-biased technology in the Yacht sector, \( z_Y \).
Proposition 1: If high-skill labor and low-skill 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.

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-skill labor, $L$, depends on the elasticity of substitution in the Potato sector. If $\sigma_F < 1$, then 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-skill labor in addition to high-skill labor. If $\sigma_F > 1$, then 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-skill 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-skill labor from the Potato sector outweighs the effect of the inflow of low-skill 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-skill labor and low-skill 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 isoultility 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 2 shows the effects of an increase in $z_Y$. The dashed lines are the new isoultility lines, and the point of tangency between the dashed lines is the new equilibrium. Note that the isoultility 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 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 isoultility 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.

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 $ar{F} = dF/F$ and $\hat{z}_Y = dz_Y/z_Y$. Then total differentiation of equations (6) through (11) yields the response of Potato production to a small change in skill-biased technology in the Yacht sector:

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

the magnitude of which is increasing in $\sigma_Y$ 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. 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. 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. 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. 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.

### 3.4 Parameterization

The model predicts that the poor’s welfare falls in response to an increase in skill-biased technology accumulation in the Yacht sector whenever the elasticity of substitution between skilled and low-skilled labor is greater than unity. If technology increases in the Potato sector as well, then the direction of the poor’s welfare change depend on the extent of the bias in technology accumulation across sectors. To get a sense for the model’s quantitative welfare

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10 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.
implications in response to changing technology, I parameterize the model to match values of the skill ratio and wage premium in 1990, which is at the beginning of the period covered by the SIPP data discussed in Section 4. In accordance with the literature on skill-biased technological change, I define skilled workers as members of the workforce with a college degree.

I set the skill ratio, $\frac{H}{L}$, equal to 1.27, based on the estimate of the fraction of workers with a college degree in Buera and Kaboski (2012). I set $\sigma_F = \sigma_Y = 2$ at the upper end of estimates of the elasticity of substitution between skilled and low-skilled workers. Finally, I choose $\eta = \mu = 0.67$ to match the wage premium in 1990, which is approximately 1.8 (see Buera and Kaboski 2012).

Table 3 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. An 80% increase in $z_Y$ requires a 28% increase in $z_F$ to ensure that the supply of Potatoes does not fall. When growth is more symmetric, the consumption and welfare of the Poor improves.

As in the canonical one-sector model in Acemoglu (1998), inequality increases in all cases. Note that the difference between $z_Y$ and $z_F$ captures the difference between technological growth in the sectors consumed by the rich and the poor. If preferences were homothetic such that consumption bundles of the rich and the poor were the same, then $z_F = z_Y$ regardless of how technological improvements were distributed across sectors. Thus the difference between $z_Y$ and $z_F$ incorporates the extent to which consumption bundles differ and the degree of nonhomotheticity in preferences.

While the evidence in Section 2 documents that growth was indeed biased toward the consumption bundle of the rich, the precise extent of that bias remains unclear given the challenges of identifying product-biased (in addition to sector-biased) growth. Measuring changes in welfare is likewise challenging given the lack of data on quality-adjusted prices of the different goods and services consumed by different subgroups of the population. Below I present evidence that is consistent with the model’s prediction of falling welfare for Americans with low levels of education.

4. Evidence of Falling Welfare
This section presents new evidence documenting that hardship increased between the 1990s and mid-2000s for Americans with low levels of education, consistent with the prediction of my
model when growth is sufficiently asymmetric. I also document that hardship increased more in states that experienced the most growth in information technology than among the states that experienced the least growth. While the evidence is far from conclusive regarding the direction of the welfare change for low-income Americans, it nonetheless contributes a new set of facts to the debate on the evolution of well-being during the latter part of the Twentieth Century. The increase in hardship suggests that costs of living may have increased for low-income Americans, consistent with public perception and consistent with the evolution of the geographic availability of services documented in Shuetz, Kolko, and Meltzer (2012).

Data. The SIPP includes well-being modules that were administered in various years between 1991 and 2004. The modules include a series of questions about respondents’ ability to meet basic needs. These questions are:

1. “During the past 12 months, has there been a time when your household did not meet all of your essential expenses?”
2. “In the past 12 months did the electric company turn off service, or the oil company not deliver at all?”
3. “In the past 4 months did you or other adults in the household ever cut the size of your meals or skip meals because there wasn’t enough money for food?”

There is also a sequence of questions that ask whether the respondent had enough to eat in each of the past five months. Evolution of Hardship. Figure 4 plots the proportion of respondents with less than a bachelor’s degree who answer “Yes” to questions 1 through 3, and who report not having enough to eat at some time in the past five months. The sample is restricted to individuals between 20 and 55 years old, although the results are similar when including elderly in the sample. For each measure of hardship, the proportion increased between 1991 and 2004. For example, the proportion unable to meet essential expenses rose 24% (from 0.165 to 0.205), and the proportion who cut or skipped meals rose 26% (from 0.025 to 0.034). For each measure, the change in

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11 I cannot rule out that changes in rules government cash assistance (in addition to sector-biased growth) may have caused increasing hardship, for example. Changes in welfare under the Personal Responsibility and Work Opportunity Act of 1996 primarily affected women with children. If I limit the sample so single males, the sample size is sufficiently small that increases in hardship are statistically significant for only two of the four measures of hardship.

12 The third question was not asked in 1991.
hardship is statistically different from zero at the p<.01 level of significance. There were also steady increases in hardship between each wave. The exceptions are “Not enough to eat,” which dipped slightly between 2001 and 2004; and “Utilities turned off,” which dipped slightly between 1991 and 1996. All four measures of hardship increased during the latter half of the 1990s, which is the time period when growth in information technology accelerated (see Stiroh 2002).\footnote{The results are similar, but more pronounced, for individuals with less than a high school degree. The sample size is sufficiently small that conditioning on covariates for age, sex, and race}

One caveat when interpreting the change in the propensity to experience hardship is that it is possible that respondents’ interpretation of the survey questions may have changed over time. However, Figure 5 shows that for the remainder of the population (those with a bachelor’s degree), the proportion reporting hardships decreased or remained constant between 1991 and 2004. Thus the difference in changes in hardship between the education groups suggests that the increasing hardship for individuals with low levels of education is indeed due to changes in well-being rather than other factors that may have affected respondents across groups.

These results are surprising in light of the fact that official measures of real GDP per capita grew by over 32% between 1991 and 2004. While it has been well documented that inequality increased during this time and that economic growth disproportionately benefitted those with a college degree, the fact that hardship appears to have increased for those with low levels of education is surprising given the predictions of standard models used to explain rising inequality.

The results are also surprising given the fact that subsets of goods appear to have become less expensive and more accessible to low-income populations. For example, Meyers and Sullivan (2011) document an increase in ownership of cars and other amenities among the lowest quintile of earners during the 1990s. However, rising hardship is consistent with other evidence that access to services has been decreasing for low-income households. According to Shuettz, Kolko, and Meltzer (2012), retail service density fell in poor neighborhoods between the 1990s and 2000s, conditional on changes in neighborhood characteristics. Thus access to basic services for poor households became more costly in terms of time and transportation as labor resources shifted from providing services for low-income individuals in poor neighborhoods to providing services in high-income areas.
Cross-Region Evidence. Here I examine whether the association over time between growth and falling welfare is also apparent when comparing different states in the U.S. If labor is fully mobile, we would not expect to see a cross-regional relationship between growth and hardship. However, moving costs and other impediments to full mobility imply that any dependence of hardship on biased growth may be evident when comparing regions with different growth rates.

Since the number of SIPP respondents is too small to precisely identify state-level changes in hardship over time, it is informative instead to compare the evolution of hardship between groups of states. While all states experienced positive IT growth, a handful of states experienced disproportionate increases in new technology.\(^\text{14}\) The states (and district) in the top decile of per capita IT increases between 1991 and 2004 are the District of Columbia, Connecticut, Massachusetts, Delaware, and Colorado. Each of these states experienced an increase in IT technology per capita that is over twice the median across states. IT growth is less skewed at the lower end of the distribution across states. Therefore we examine a larger comparison group consisting of states in the lowest quartile of changes in output of IT-intensive industries per capita (Alabama, Kentucky, Montana, Indiana, Idaho, Oklahoma, Arkansas, Wyoming, South Carolina, New Mexico, Louisiana, Mississippi, West Virginia, and Hawaii).

Table 4 compares the evolution of “unable to meet basic expenses” and “not enough to eat” from 1991 to 2004 between high-growth states and low-growth states. The changes in the average number of respondents identifying each of these measures of hardship are statistically different from zero at the p<.01 level of significance. The third measure of hardship that is available in 1991, “utilities turned off,” did not change significantly for either group of states. According to Table 4, the group of states with the largest increases in information technology also experienced larger increases in both measures of hardship. Thus the relationship between growth and hardship over time also appears to hold when comparing states of different levels of growth.

\(^{14}\) The Bureau of Economic Analysis provides historical data on industry-level output for each state. See Section 2.2 for which industries are considered IT-intensive. I consider IT growth to be the relevant statistic for comparison based on the evidence in Section 2.2 below that growth was biased toward IT during the time period considered, and based on the predictions of the model in Section 3. The results are similar when examining changes in total GDP due to the high correlation between IT growth and aggregate growth across states.
The relationship between technological growth and hardship is contrary to the predictions of standard economic models, including those that explain rising inequality through skill-biased technological change. However, it is consistent with my model of asymmetric growth.

6. Conclusion
This paper documents that growth has been biased toward the consumption bundle of the rich and proposes a model to explain the fall in welfare of the poor based on this form of asymmetric growth. The key mechanism driving the result 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 model presented above and models of inequality is that the model above accounts for the fact that consumption bundles are not identical across the population.

The theory offers new insights into the forces that affect the evolution of welfare. An important implication is that a comprehensive understanding of the evolution of well-being requires information on quality-adjusted costs of attaining all goods and services in consumption bundles. Therefore results based on scanner data or consumption of particular goods offer an incomplete picture of well-being. A more complete picture will emerge with the availability of data on access to and quality of services consumed by subsets of the population.

While the paper has focused on a particular type of asymmetric growth, the mechanism responsible for falling welfare may apply in a number of other contexts, including international trade. It may also adversely affect the rich instead of the poor, depending on the nature of the biased growth. If, for example, growth in China is biased toward its service sector then costs may increase and welfare may decrease for its richer trading partners.

References


Appendix A

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

\[ \bar{H}_F = -\frac{(\sigma_Y - 1)(\sigma_Y L_F + L_Y)H_Y}{H_F[(\sigma_Y L_F + \sigma_Y L_Y)] + H_Y[(\sigma_F + \sigma_Y - 1)L_F + \sigma_Y L_Y]} \bar{Z}_Y \]  \hspace{1cm} (A1)

and

\[ \bar{L}_F = \frac{(\sigma_F - 1)(\sigma_Y - 1)\sigma_Y L_Y}{(\sigma_F H_F + \sigma_Y H_Y) L_F (\sigma_Y - 1) + (\sigma_F L_F + \sigma_Y L_Y)(H_F + \sigma_Y H_Y)} \bar{Z}_Y, \]  \hspace{1cm} (A2)

where \( \bar{x} = dx/x \) 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:

\[ \frac{dF}{F} = \frac{\sigma_F}{\sigma_F - 1} \left[ \frac{\sigma_Y H_Y L(\sigma_Y - 1)(1 - \eta)L_F^{-\frac{1}{\sigma_F}}}{(\sigma_F H_F + \sigma_Y H_Y) L_F (\sigma_Y - 1) + (\sigma_F L_F + \sigma_Y L_Y)(H_F + \sigma_Y H_Y)} \right] \times \bar{Z}_Y, \]

Substituting in (A1) and (A2) yields

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

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

$$\text{max } Y_R$$

s.t. $H_w = Y_p$  \hspace{1cm} (B1)

Likewise, the Poor agents solve

$$\text{max } 1.5 \times \log(F_p + 1)$$

s.t. $L_w = F_p$  \hspace{1cm} (B2)

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

$$c_F(w_H, w_L) = p_F$$  \hspace{1cm} (B3)

$$c_Y \left( \frac{w_H}{z}, w_L \right) = p_Y.$$  \hspace{1cm} (B4)

Market clearing implies

$$H_F + H_Y = H$$  \hspace{1cm} (B5)

$$L_F + L_Y = L.$$  \hspace{1cm} (B6)

Shepard’s Lemma determines conditional factor demands in the Potato sector:

$$\frac{\partial c_F}{\partial w_H} = \frac{H_F}{F}$$  \hspace{1cm} (B7)

$$\frac{\partial c_F}{\partial w_L} = \frac{L_F}{F}$$  \hspace{1cm} (B8)

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

$$\frac{\partial Y}{\partial H} / \frac{\partial Y}{\partial L} = \frac{r}{w}.$$  \hspace{1cm} (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:
\[ \hat{w}_H = \hat{y} + \hat{p}_Y \]  
\[ \hat{w}_L = \hat{f} + \hat{p}_F \]  
\[ \phi_H \hat{w}_H + \phi_L \hat{w}_L = \hat{p}_F \]  
\[ \theta_H \hat{w}_H + \theta_L \hat{w}_L = \theta_Z \hat{z} + \hat{p}_Y \]  
\[ \lambda_{H_F} \hat{H}_F + \lambda_{H_Y} \hat{H}_Y = 0 \]  
\[ \lambda_{L_F} \hat{L}_F + \lambda_{L_Y} \hat{L}_Y = 0 \]  
\[ \hat{H}_F = \hat{f} + \phi_H \sigma_F (\hat{w}_L - \hat{w}_H) \]  
\[ \hat{L}_F = \hat{f} + \phi_L \sigma_F (\hat{w}_H - \hat{w}_L) \]  
\[ \hat{H}_Y - \hat{H}_Y + (\sigma_Y - 1) \hat{z} = \sigma_Y (\hat{w}_H - \hat{w}_L) \]  

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 \( \sigma_F \) in the Potato sector. In the Yacht sector \( \sigma_Y \) in the elasticity of substitution between \( z_H \) 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:

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

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

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

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

and the Poor agent solves

$$ \max 0.5 \times \log(F) \quad \text{s.t.} \quad w_L L \geq rK_F + w_H H_F + w_L L_F, $$

25
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,

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

and

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

and two equations in the Potato sector,

$$\frac{\eta}{1 - \eta} (1 - \lambda) \left( \lambda K_P^{\frac{\sigma_P - 1}{\sigma_P}} + (1 - \lambda) H_P^{\frac{\sigma_P - 1}{\sigma_P}} \right)^{\frac{\beta - \sigma}{\beta (\sigma - 1)}} \frac{1}{L_P K_P} \frac{1}{\sigma_P} = \frac{r}{w_L} \quad \text{(C5)}$$

and

$$\frac{\eta}{1 - \eta} (1 - \lambda) \left( \lambda K_P^{\frac{\sigma_P - 1}{\sigma_P}} + (1 - \lambda) H_P^{\frac{\sigma_P - 1}{\sigma_P}} \right)^{\frac{\beta - \sigma}{\beta (\sigma - 1)}} \frac{1}{L_P H_P} \frac{1}{\sigma_P} = \frac{w_H}{w_L} \quad \text{(C6)}$$

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

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

fully characterize the competitive equilibrium.

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

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

I set $\frac{H}{L} = 0.7$ 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 $\mu$ increases the relative skill intensity in the Yacht sector, consistent with the evidence in Buera and Kaboski (2012). 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 $\sigma_Y$ relative to $\gamma$), 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 inflow of capital to the Potato sector. If the baseline calibration is changed slightly to decrease the relative complementarity (through either an increase in $\sigma_Y$ or a decrease in $\gamma$), 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>
<thead>
<tr>
<th>$\bar{w}_H$</th>
<th>$\hat{r}$</th>
<th>$\bar{K}_F$</th>
<th>$\bar{H}_F$</th>
<th>$\bar{L}_F$</th>
<th>$\bar{F}$</th>
<th>$\bar{Y}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.59%</td>
<td>-1.70%</td>
<td>0.51%</td>
<td>-1.45%</td>
<td>0.29%</td>
<td>-0.43%</td>
<td>2.07%</td>
</tr>
</tbody>
</table>

Note: The price of low-skilled labor, $w_L$, is normalized to 1.
Table 1-Consumer Goods Associated with IT-Intensive Industries

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Telecommunications</td>
<td>5133</td>
<td>16.9%</td>
<td>TV and Radio Services</td>
</tr>
<tr>
<td>Professional services</td>
<td>5413, 6220</td>
<td>7.7%</td>
<td>Legal and Medical services</td>
</tr>
<tr>
<td>Credit intermediation and related activities</td>
<td>52A0</td>
<td>7.2%</td>
<td>Financial Services</td>
</tr>
<tr>
<td>Air transportation</td>
<td>4810</td>
<td>5.2%</td>
<td>Air transportation</td>
</tr>
<tr>
<td>Cable networks</td>
<td>5131, 5132</td>
<td>5.0%</td>
<td>TV and Radio Services</td>
</tr>
</tbody>
</table>

Note: Industry-level expenditure on IT is from the The 1997 Capital Flow Table. The mapping between industries and consumption expenditure categories is based on the BEA Input-Output Commodity Table 2.5.2U.

Table 2-Expenditure Shares by Income Category on IT-Intensive Consumer Goods

<table>
<thead>
<tr>
<th>Income Percentile Category</th>
<th>Financial Services, Communication, Professional Services, and Air</th>
<th>Financial Services</th>
<th>Financial Services, Professional Services, and Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%-35%</td>
<td>15.0%</td>
<td>6.6%</td>
<td>8.7%</td>
</tr>
<tr>
<td>35%-50%</td>
<td>20.7%</td>
<td>12.1%</td>
<td>14.9%</td>
</tr>
<tr>
<td>50%-70%</td>
<td>24.4%</td>
<td>15.8%</td>
<td>18.8%</td>
</tr>
<tr>
<td>70%-100%</td>
<td>26.5%</td>
<td>18.4%</td>
<td>21.9%</td>
</tr>
</tbody>
</table>

Note: Data are from the 2009 Consumer Expenditure Survey. Financial Services include mortgage interest, accounting fees, and other finance charges (Universal Classification Codes 220311, 220311, 680902, and 710110). Communication includes computer-related purchases and telephone, television, satellite, and radio services (codes 270102, 270103, 270310, 270311, 310334, 310334, 690111-690117, 690310, 690320, and 690350). Professional Services include legal and medical services (codes 680110, 560110, 560210, 560310, 560330, and 560400). Air travel includes codes 450900, 460903, 450906, and 530110.
### Table 3: Response of Consumption by the Poor to Skill-Biased Technological Improvements

<table>
<thead>
<tr>
<th>Increase in $Z_y$</th>
<th>Increase in $Z_f$</th>
<th>Change in $F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>0%</td>
<td>-15%</td>
</tr>
<tr>
<td>95%</td>
<td>6%</td>
<td>-12%</td>
</tr>
<tr>
<td>90%</td>
<td>12%</td>
<td>-9%</td>
</tr>
<tr>
<td>85%</td>
<td>20%</td>
<td>-4%</td>
</tr>
<tr>
<td>80%</td>
<td>28%</td>
<td>0%</td>
</tr>
<tr>
<td>75%</td>
<td>37%</td>
<td>5%</td>
</tr>
<tr>
<td>70%</td>
<td>48%</td>
<td>11%</td>
</tr>
</tbody>
</table>

Note: Each column generates an equivalent increase in the skill premium.

### Table 4: Evolution of Hardship Among Low-Growth States and High-Growth States

<table>
<thead>
<tr>
<th>Absolute change in the mean number of respondents with less than a bachelor’s degree reporting hardship, 1991 to 2004</th>
<th>Unable to meet basic expenses</th>
<th>Not Enough to Eat</th>
</tr>
</thead>
<tbody>
<tr>
<td>States with largest increases in IT-intensive industry output per capita</td>
<td>0.050</td>
<td>0.018</td>
</tr>
<tr>
<td>States with smallest increases in IT-intensive industry output per capita</td>
<td>0.026</td>
<td>0.012</td>
</tr>
<tr>
<td>Difference</td>
<td>0.024</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Note: Data are from the SIPP in 1991 and 2004. Changes in hardship for each group are different from zero at the p<.01 level of significance. States included in the first row are District of Columbia, Connecticut, Massachusetts, Delaware, and Colorado. States in the second group are Alabama, Kentucky, Montana, Indiana, Idaho, Oklahoma, Arkansas, Wyoming, South Carolina, New Mexico, Louisiana, Mississippi, West Virginia, and Hawaii.
Figure 1: Edgeworth Box Representation of the Equilibrium.
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: Income and Substitution Effects from an increase in $z_Y$. 

[Diagram showing income and substitution effects with labeled axes and points indicating endowment, new equilibrium, income effect, and substitution effect.]
Figure 4: Percent Reporting Measures of Hardship, Individuals with Less Than a Bachelor's Degree

Figure 5: Percent Reporting Measures of Hardship, Individuals with More Than a Bachelor's Degree