Search Engines vs Steam Engines: Theory and Some Evidence on Technology, Career Choice and the Income Distribution

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Abstract: This paper considers the implications of two types of technological change for the income distribution within a unified model in which occupational choice plays a key role. Type A technological change allows unskilled labor to produce a greater quantity of output per unit of time. It increases the return to unskilled labor, but raises the return to human capital by an even larger amount through a general equilibrium effect, thereby increasing inequality. Type B technological change expands the scale of operation for workers within an occupation, such that a given quantity of output generates greater value for the worker. Technological progress of this type is modeled as an increase in the limit over which the production technology of an occupation displays Increasing Returns to Scale. It hurts the least talented workers while possibly benefitting the most talented ones, thus increasing income inequality within the occupation. We compare the theoretical results with U.S. data and finds support for the predictions.

JEL: J24, J31, O30, D33

Keywords: income inequality, technological change, increasing returns to scale

1. Introduction

It has been widely noted that we are in a period of rapid technological change with important implications for the income distribution. In this paper we differentiate between two types of technological change: one, which we call type A, enables workers to produce more output per unit of time – for instance, the invention of the steam engine; the other, type B, increases productivity by expanding workers' reach or "scale of operation". This type of technological change increases the value generated by a given amount of output, rather than increasing the quantity of output produced per unit of time. One example is the invention of the radio which allowed a singer's voice to be heard far beyond the walls of a theatre, but did not enable her to sing more songs per hour. Similarly, the invention of the Internet has spawned a "New Economy",[1] in which individuals sell their services or products online, often on organized exchanges such as Etsy, Alibaba, eBay, and Amazon. While the Internet does not reduce the time or effort required of a retailer to develop a marketing strategy, it does enable any particular strategy to reach customers far beyond what face-to-face interaction would allow. This paper considers both types of technological change in a unified model and finds that they have very different implications for the income distribution as well as individual's career choice.

The importance of scale of operation has not gone unnoticed: a strand of the literature beginning with Rosen (1981) has applied this notion to explain certain features of the income distribution. However, as we describe further below, this literature has not formally analyzed the effects of an increase in the scale of operation, as we do here. Our modeling approach rests on a key observation: for occupations in which "scale of operation" is an important determinant of workers' income, the production technology displays Increasing Returns to Scale *up to some Limit* (which we denote IRSL), and this limit marks the scale of operation and may increase over time. Note that taking the limit to infinity, IRSL subsumes IRS as a special case.

To be more specific, the IRS component of IRSL is typically driven by the fact that once a worker has employed her human capital to produce her stream of services, the services can then be simultaneously consumed by a number of people (e.g., music) or can be combined together with a number of other resources into production (e.g., managerial strategy) without reducing its effect and at a constant marginal cost. That is, having paid a fixed cost, reflected in the opportunity cost and the disutility of using her human capital, the worker can create value at constant returns

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[1]This term seems to have originated in a *Time* magazine cover story in 1983 that discussed the transition from an industrial economy to a more technologically-oriented service economy. See "The New Economy" by Charles P. Alexander, *Time* magazine, May 30, 1983.

to scale (CRS). Our innovation consists in the observation that the CRS often operate up to some limit. For example, it is costly for a musician to create good music, but it costs very little to admit an additional person into a theater to hear it (or to produce one more digital copy of it), up until the point at which the theater is filled (or the population of possible buyers has been reached). The capacity of the theater (or the size of that population) thus defines the limit of IRS for the musician. Similarly, a retailer does not need to exert ever greater effort in describing a product as the set of potential customers grows. Therefore, the marketing technology displays IRS up to the size of the customer base, which defines the scale of operation for the retailer in terms of marketing. As another example, while it may be costly for the manager of a firm to identify a profitable strategy, once one has been identified the profit it generates may rise in proportion to the resources that are deployed – i.e., at CRS – until the firm's resources have been expended. The scale of these resources, i.e., the firm's size, is thus the limit of IRS for the manager's job and defines his scale of operation.

We also note that scale of operation and income are typically tightly linked in the case of human-capital-intensive occupations, something that is much less true of labor-intensive occupations. This is because labor – i.e., the human body – is a relatively homogenous input: in most instances one individual's labor can substitute for another's. On the other hand, human capital – i.e., the human mind – is much more idiosyncratic and diverse. As a result, workers in human-capital-intensive occupations usually produce differentiated products or services, such that the market can be characterized by monopolistic competition. The effective monopoly that these workers hold over their services allows them to capture the surplus associated with sales brought about by a given quantity of their service, thus linking their income to their scale of operation. On the other hand, labor providers compete in a labor market that is much more competitive and are therefore much less likely to capture the gains from additional sales.

Our model captures these observations. In the model, we consider a continuum of agents with equal endowments of labor but heterogeneous endowments of human capital. They choose to subsist either by employing their labor, or by employing their human capital, thereby becoming a professional – for instance, a singer – for which the quality of their output depends on the size of their human capital endowment.[2] Professionals hire labor in order to produce a stream of services and labor is also separately used to produce a subsistence good. Labor is homogenous and its providers compete under perfect competition. In contrast, the services provided by individual professionals are differentiated, for instance Madonna versus Jay-Z. As a result, professionals compete via monopolistic competition. We assume that after committing his time to supply human capital rather than labor, a professional hires labor to produce his variety of services at constant returns to scale

[2]This feature of an identical labor endowment and heterogeneous human capital (or ability) is also found in Lucas Jr (1978) and Monte (2011).

up to the limit B. This B therefore represents the maximum scale of operation for a professional – for example, the capacity of the theater in which a musician performs. Technological progress of type B increases the maximum scale of operation for all professionals, but does not necessarily increase the *actual* scale of operation for a *particular* professional, which depends on the degree of competition and factors on the demand side.[3] The productivity of labor, measured by the quantity of the subsistence good produced per unit of labor, is A. Therefore, an increase in A reflects type-A technological progress. This paper focuses on the implications of a rise in A or B for the income distribution and career choice.

Consider an increase in B. On the one hand, each professional can produce more, which benefits them. On the other hand, since the production capacity of all professionals increases, each of them faces fiercer competition. While this increase in competitive pressure is the same for all professionals, the expansion in output capacity delivers greater benefits to those who have more human capital and are therefore able to charge a higher price for their stream of services. This results in two outcomes. (a) Income inequality between professionals increases: there exists a critical level of human capital such that professionals with human capital below this point lose and those beyond it realize net gains from the increase in B. (b) Another, lower threshold of human capital exists such that practitioners below this point are squeezed out of the profession and must subsist on the provision of their labor. As a result, the number of varieties is reduced. This result may partly explain a range of anecdotal observations, such as the increased difficulty in finding success as a local comedian following the advent of television or reduced opportunities for travel agents due to the Internet.

Next consider an increase in A, the productivity of labor. This increases the real income of those who choose to supply labor. However, due to a general equilibrium effect, it increases the income of those who choose to become professionals even more, and the higher their human capital, the greater the rise in income. The intuition is as follows. First, the primary impact of an increase in A is to raise aggregate income. Second, since agents with higher earnings acquire a larger fraction of aggregate income, a larger fraction of the increase in the aggregate income accrues to them. As a result, an increase in A (c) increases income inequality, while (d) also increasing the income level of all workers. With respect to occupational choice, we show that (e) an increase in A drives agents out of supplying labor and into professional work. This is because the increase in labor productivity reduces the demand for labor in production such that workers increasingly employ their human capital in the workplace, for instance becoming dancers, painters, singers, writers etc. Moreover, with the economy becoming richer the demand for these services rises, thereby leading the marginal

[3] For example, the Internet may enable a singer to access hundred millions of potential customers, but the singer will likely be unable to sell to each of these people.

laborers to shift to the provision of services.

We extend our model to consider the impact that an increase in the IRS limit in one occupation has on another occupation for which the limit of IRS is unchanged (which we refer to as an "unaffected" occupation). We show that (f) an increase in the limit of IRS for the affected occupation may reduce the income of *all* practitioners in the unaffected occupation, mainly by making its services or products relatively cheaper.

In a final section we discuss the extent to which the model is consistent with the empirical evidence. We first discuss the predictions with respect to type A technological change in the context of developing country growth, where we argue that our mechanism can provide an explanation for the observed relationship between aggregate economic growth and rising inequality in countries such as China. The so-called Kuznets curve depicts this relationship and is typically explained as the result of the movement of unskilled labor from rural to urban areas; we provide evidence indicating that our general equilibrium mechanism represents a plausible complementary explanation and, furthermore, is consistent with the shift toward a services-oriented economy.

We then explore type B technological change using U.S. data where we exploit the natural experiment generated by the rapid expansion of global Internet access beginning in the mid-1990s. Specifically, we test the hypothesis that this growth in the Internet led to rising wage inequality and falling employment in the most affected occupations. Formally, we construct a measure of the extent to which the stream of services associated with each U.S. occupation generated Internet sales in each year over the period 1995-2006. An increase in this measure for a particular occupation therefore reflects an increase in the reach or scale of operation for those workers – i.e., an increase in the limit of IRS. In a regression framework we then test the relationship between this measure and changes in wage inequality and employment across occupations, controlling for pre-Internet trends and potentially confounding variables.

Noting that our analysis should be interpreted as suggestive rather than definitive, consistent with prediction (a) we find that Internet-affected occupations saw widening wage inequality during the Internet period that included wage losses for lower-end workers. We also test the model's predictions with respect to patterns of employment, given by results (b) and (e) above. Taken together, these results predict that relative to unaffected occupations, the employment in affected occupations will fall due to the effects of the Internet. We find some evidence in favor of this prediction.

The paper proceeds as follows. Section 2 places our paper within the existing literature. Sections 3 and 4 present our theory of technological change. Section 5 brings some predictions of the model to the data. Section 6 provides some concluding remarks.

2. The Literature

A major theme of our paper, that technological development increases income inequality, fits within a large literature that approaches the topic from a variety of perspectives. The dominant theoretical framework is that of Skill-Biased Technical Change (SBTC),[4] which is certainly an important contributor to recent trends in wage inequality, and is possibly the most important one. With this in mind, the paper presented here is intended as a complement to this literature in that we consider other facets of technological progress.

Specifically, our contribution is twofold. First, we adopt the notion of ISRL to model type B technological progress, which represents a new way of modeling technology relative to the conventional approach which models technology as a labor- (or capital-) augmenting factor. With this modeling approach in hand, we uncover a new mechanism through which technological changes affect the income distribution, while also deriving new empirical implications. As noted, type B technological change alters the income distribution through competition and workforce reallocation, a mechanism that has little in common with the standard SBTC model. One important result is that type B technological change differentially affects workers who are engaged in *the same type of work*.[5] In contrast, the explanatory power of SBTC models derives from heterogeneity in the nature of workers' tasks, namely the extent to which new technologies complement them or substitute for them. As a result, SBTC models have difficulty explaining the within-occupation response to technological change for occupations in which workers perform similar tasks – i.e., tasks that are affected by technological change in the same way (e.g., singers or eBay merchants). At the same time, there is empirical evidence that within-occupation variation is important, to which our empirical results in Section 5 contribute. As recent examples, Goos and Manning (2007) for the U.K. and Helpman, Itskhoki, Muendler and Redding (2012) for Brazil find that recent growth in inequality has occurred largely within occupations.

Second, type A technological change, while directly augmenting factor productivity as in the standard SBTC model, is biased toward unskilled workers in this paper rather than toward skilled workers. Despite its unskilled-bias, type A technological progress *increases* income inequality due to a general equilibrium effect in which the highest earners reap the largest gains from the techno-

[4] As just a few representative examples: Tinbergen (1974) is an example of early work linking the demand for skill to technology; Autor, Levy and Murnane (2003) find that computers displace routine workplace tasks and complement cognitive-intensive, non-routine tasks; Firpo, Fortin and Lemieux (2012) adopt a novel decomposition approach and find an important role for technology in generating the observed inequality pattern over the 1980s, 1990s, and 2000s; Beaudry, Doms and Lewis (2010) find that computer adoption increases the return to skill; and Chen, Forster and Llena-Nozal (2013) find that technology has increased inequality across OECD countries.

[5] The differential effects in our paper arise from differences in workers' human capital endowments. This approach to generating differences in income is in line with the literature that is built on the matching model of Sattinger (1993). Also, in a recent paper Guvenen and Kuruscu (2012) show that simply adding heterogeneity in the ability to accumulate human capital to a standard SBTC framework generates a set of predictions for wages that mirrors features of the U.S. wage distribution over the past four decades.

logical advance. This effect has so far been missing in the SBTC literature and the result directly contrasts with the implications of that literature, in which unskilled-biased technologies should *decrease* inequality.[6]

Beyond SBTC, the role of scale of operation as it relates to the return to skill has long been noted in the literature in order to explain certain features of the income distribution. In particular, the earnings of "superstars" or CEOs have been the focus of, among others, Rosen (1981), Rosen (1983), Gabaix and Landier (2006), and Egger and Kreickemeier (2012) (see Neal and Rosen (2000) for a summary).[7] However, these models differ from our approach in three primary ways. First, this literature is mainly concerned with the level of income inequality for a given level of technology, and in particular in explaining how small differences in talent can lead to large differences in income – that is, the literature is interested in explaining why income is a convex function of talent. At the same time, it offers only an informal discussion regarding the potential impacts of an increase in the scale of operation.[8] In contrast, we formally consider the implications of this type of change.[9] Second, our model is ultimately not about superstars. We study the career choice margin, between providing labor and becoming low-end professionals (who are certainly not superstars), whereas this margin is not studied in that literature. Finally, we jointly consider technological changes of types A and B with a unified framework.

Our model has some of the flavor of Melitz (2003),[10] though the two papers are concerned with different issues. Specifically, our paper is concerned with the effects of technological progress on the income distribution and career choice in a closed economy, while Melitz (2003) is mainly focused on the relationship between exporting and aggregate productivity in an open economy. Both papers feature monopolistic competition with CES preferences, IRS, and agent heterogeneity, and

[6]Canidio (2013) also presents a model in which technological change that is not biased toward skilled labor can lead to long-run (i.e. steady state) inequality. In his model, inequality arises from the interaction between investments in skill and borrowing constraints. This is quite different than the mechanism in our model, in which inequality is driven by heterogeneity in human capital, as noted above.

[7]The scale of operation in Rosen (1981) is the size of the market that a superstar can capture; in Rosen (1983) it is the span of control to which managerial talents are applied; in Gabaix and Landier (2006) it is the size of the firms to which CEOs are assigned (following assignment models of Sattinger (1993) and Teulings (1995); and in Egger and Kreickemeier (2012) it is the number of workers, the productivity of whom all is increased by a more-able manager.

[8]Interestingly, Garicano and Rossi-Hansberg (2014) extend the model developed by Lucas Jr (1978) in order to demonstrate the implications of ICT innovation for the income distribution. They model this progress as a reduction in the rate at which the marginal return to labor falls. This increases the scale of operation for managers in equilibrium. Relative to this approach, our model incorporates the fact that type B progress can increase competition between workers, which consequently generates losses for a subset of them. In contrast, in the re-interpretation of Lucas Jr (1978) by Garicano and Rossi-Hansberg (2014), this effect is absent, and no manager loses from the ICT progress.

[9]Rosen (1981) speculates that one outcome of such progress would be "greater rents for all sellers", whereas we show that an increase in B unambiguously reduces the income of those whose human capital is below some threshold (see result (a) above). Moreover, many studies of that literature speculate that a type B progress *always* makes the top practitioners earn more, whereas we show that this is not always true and depends on the degree of competition between the practitioners and the distribution of their human capital.

[10]More accurately, our model is in line with Melitz (2003)-style models that incorporate heterogeneity in product quality, since the heterogeneity we introduce augments the marginal value of a unit of consumption, as in those models. For instance, see Baldwin and Harrigan (2007) or Kugler and Verhoogen (2012).

an increase in B in our paper might be regarded as parallel to an increase in the number of trading partners in Melitz (2003), since each of these reflects an increase in market size. However, in terms of modeling there is an important difference between this paper and Melitz (2003), namely that in our paper IRS operates up to some finite limit, whereas in Melitz (2003) this limit is infinity. As a result, we show that an expansion in the limit of IRS increases product market competition which leads to a fall in the price of each service variety, a product market effect that is absent in Melitz (2003). On the other hand, this effect is captured by Melitz and Ottaviano (2008) using a model of monopolistic competition with quadratic preferences. However, this approach then leads to different implications for changes in market size. Whereas in Melitz and Ottaviano (2008) a larger market supports a greater number of varieties, in our paper an increase in the limit of IRS (which could be considered to be similar to an increase in market size) reduces the number of varieties.

There is other theoretical work that studies the effects of technological progress on the income distribution from a different angle or in a different context. For instance, Jones and Kim (2012) endogenize the Pareto income distribution in a model in which technological progress augments the effects of entrepreneurs' efforts to increase productivity. Garicano and Rossi-Hansberg (2004, 2006) and Saint-Paul (2007) examine the effects of reduced communication costs on the income distribution, where knowledge production and the organization of this production play an important role. Saint-Paul (2006) studies how productivity growth affects income inequality when consumers' utility from product variety is bounded from above.[11]

3. The Model

The economy is populated by a continuum of agents. Agent $i \in [0, 1]$ is endowed with one unit of labor and h_i units of human capital. Without loss of generality, let h_i be increasing in i, that is $h_i' := \frac{dh_i}{di} \geq 0$. Agents choose to live on their labor endowment or else on their human capital.[12] In the latter case, they provide a stream of services which, to fix ideas, we assume throughout to be entertainment services. The quality of the services provided by an agent depends on the size of his human capital endowment and, for simplicity, is assumed to be equal to it.

Labor is used for producing both a subsistence good (such as food) and entertainment services. The production of the subsistence good is subject to perfect competition and displays constant

[11] More generally, the forces influencing the income distribution of an economy are clearly numerous and interrelated, and technological progress constitutes but one potential influence. Beyond the effects of technology, the economics literature has explored many other factors, such as globalization (see Haskel, Lawrence, Leamer and Slaughter (2012)), demographic changes, labor rents, unions, and the minimum wage, to name just a few (see Katz and Autor (1999) for a survey of this literature).

[12] Of course, in reality nearly all occupations require both labor and human capital. But clearly some occupations demand more human capital relative to labor, while others demand relatively more labor. For simplicity, we abstract from this continuum of human capital-to-labor ratios, modeling it as a binary choice.

returns to scale. If L agents are employed to produce the subsistence good, then its aggregate output is

$$Y = AL.$$

Within the entertainment occupation, entertainment services provided by different agents are each unique in some dimensions (for instance, consider the difference between Jay-Z and Madonna) and thus compete under monopolistic competition. As a result, each entertainer provides a unique variety of entertainment services, indexed by his identity $i \in [0, 1]$. To produce his entertainment services, an agent needs to hire labor. If he hires L units of labor, the output of his variety is

$$y = \left\{ \begin{array}{c} \frac{A}{c}L, \text{ if } L \leq \frac{c}{A}B \\ B, \text{ if } L > \frac{c}{A}B \end{array} \right\}, \tag{1}$$

Thus the agent, having committed his time to supply human capital rather than labor, can hire labor to produce output at constant returns to scale up to the limit B – that is, his production technology displays IRS up to some limit (IRSL). Note that in the production function above we abstract from the effect of human capital on the *quantity* of output. Human capital is therefore employed to produce a unique variety of a certain *quality*. If labor's wage is given by w, then the associated cost function is

$$C(y) = \left\{ \begin{array}{c} F + w\frac{c}{A}y, \text{ if } y \leq B \\ \infty, \text{ if } y > B. \end{array} \right\}, \tag{2}$$

where F is the opportunity cost of the agent's time. Since the alternative use of his time is to supply labor, then $F = w$. Here we can again see that the production of entertainment services is subject to IRSL.

Agents have identical preferences. If an agent consumes s units of the subsistence good and e_i units of variety i of entertainment services, where $i \in E$ and E is the set of varieties of entertainment services available on the market, then his utility is

$$\left(\mu s^{\widehat{\rho}} + \left(\int_E (h_i e_i)^{\rho}\right)^{\widehat{\rho}/\rho}\right)^{1/\widehat{\rho}},$$

where $\mu > 0$ measures the relative importance of the subsistence good in the agent's utility function; $\widehat{\rho} \in [0, 1)$ measures the substitutability between the subsistence good and entertainment services; and $\rho \in (0, 1)$ measures the substitutability between one entertainment service and another. Assume $\widehat{\rho} < \rho$, namely that the subsistence good is less substitutable for entertainment services than one variety of entertainment service is to another.

We set the subsistence good as the numeraire. Let p_i denote the price of variety i of entertainment services and let m denote the income of an agent. Then, the consumption decision that the agent faces is

$$\max_{s,\{e_i\}_{i\in E}} \Big(\mu s^{\widehat{\rho}} + \big(\int_E (h_i e_i)^{\rho}\big)^{\widehat{\rho}/\rho}\Big)^{1/\widehat{\rho}},$$
$$\text{s.t. } s + \int_E p_i e_i \leq m.$$

His demand for the subsistence good and entertainment services is, respectively:

$$\begin{aligned} s &= m \cdot \frac{1}{1+\mu^{1/(\widehat{\rho}-1)}P^{\widehat{\rho}/(\widehat{\rho}-1)}} \\ e_i &= m \cdot f(P,\mu) \cdot h_i^{\rho/(1-\rho)} p_i^{-1/(1-\rho)}, \end{aligned} \tag{3}$$

where the aggregate price index of entertainment services is

$$P := \Big(\int_E (p_i/h_i)^{\rho/(\rho-1)}\Big)^{(\rho-1)/\rho} \tag{4}$$

and the function $f(P,\mu)$ is given by

$$f(P,\mu) := \frac{P^{\frac{\rho-\widehat{\rho}}{(1-\rho)(1-\widehat{\rho})}}}{\mu^{\frac{1}{1-\widehat{\rho}}} + P^{\frac{\widehat{\rho}}{\widehat{\rho}-1}}}.$$

Given price p, the aggregate demand for a particular variety of entertainment services of quality h (also equal to the human capital endowment of the entertainer) is

$$D(p;h) = M \cdot f(P,\mu) \cdot h^{\rho/(1-\rho)} p^{-1/(1-\rho)}, \tag{5}$$

where

$$M := \int_{[0,1]} m_i \tag{6}$$

is aggregate income.

If an agent with human capital h chooses to supply labor and produce the subsistence good, he gets A, which is also the wage of labor employed in the production of entertainment services – that is, $w = A$. Therefore, by (2), the marginal cost of producing entertainment up to scale B is $w\frac{c}{A} = c$. If the agent chooses to live on his human capital, thereby becoming an entertainer, the demand for his variety of services will be given by (5), where he takes the aggregate variables P and M as given. He then sets the price of his services by solving the following decision problem:

$$m(h) = \max_p (p-c)D(p;h), \text{ s.t. } D(p;h) \leq B \tag{7}$$

The agent chooses to provide entertainment services instead of supplying labor only if

$$m(h) \geq A \tag{8}$$

From the envelope theorem and (7), $m'(h) > 0$. There thus exists a critical value $k \in [0, 1]$ such that agent i chooses to provide entertainment services, if and only if $i \geq k$, where k is pinned down by

$$m(h_k) = A.^{13} \tag{9}$$

For $i < k$, agent i earns wage $w = A$, and for $i \geq k$ agent i earns $m(h_i)$, the rents associated with his human capital.

Assuming $E = [k, 1]$, the price index for entertainment services, from (4), is given by

$$P = \Big(\int_k^1 (p_i/h_i)^{\rho/(\rho-1)} \Big)^{(\rho-1)/\rho} \tag{10}$$

Definition 1. *A profile (P, k, M) forms a competitive equilibrium if*

(i) P is given by (10), where p_i solves (7) with $h = h_i$;

(ii) agent i chooses to supply labor if and only if $i < k$ where k is determined by (9);

(iii) Aggregate income is

$$M{=}kA + \int_k^1 m(h_i), \tag{11}$$

where $m(h)$ is defined by (7).[14]

For technical reasons which we will explain, we assume that

$$\max_{x \in [k_0, 1]} \frac{h'_x/h_x}{1 + h'_x/h_x \cdot (x - k_0)} < \frac{1}{1 - k_0}, \tag{12}$$

where

$$k_0 = \frac{Bc}{A + Bc}.$$

This condition concerns the distribution of human capital and follows from a more intuitive condition, namely that $[\log h(x)]' < 1/(1 - x)$,[15] which says that $\log h(x)$ does not grow too fast.

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[13] More generally, k satisfies $\left\{ \begin{array}{c} k = 0 \text{ if } m(h_0) > A \\ k = 1 \text{ if } m(h_1) < A \\ m(h_k) = A \text{ if } m(h_0) < A < m(h_1) \end{array} \right\}$. The first two cases capture the possibilities that no one produces the subsistence good and that no one produces any entertainment services. With CES preferences, neither occurs in equilibrium because if no one produces the subsistence good, the marginal utility from consumption will be infinitely large, and providing it will be very profitable. This argument also applies to the case in which no one provides entertainment services.

[14] We skip the clearing of the subsistence good market, which pins down the fraction of labor used for producing the good, a variable that is not very interesting in the context of this paper.

[15] This comes from $\frac{h'_x/h_x}{1+h'_x/h_x \cdot (x-k_0)} = [1/(h'_x/h_x) + x - k_0]^{-1} < [1 - x + x - k_0]^{-1} = \frac{1}{1-k_0}$.

4. Two Categories of Technological Advancement

In this section we prove the existence and uniqueness of an equilibrium, and then consider comparative statics with respect to A and B. Here we consider only the case in which the capacity constraint, $D(p;h) \leq B$, is binding for the agents who choose to be entertainers, which effectively requires B to be sufficiently small.[16] The insights derived from this case can then be applied straightforwardly to the case in which the capacity constraint is binding for some entertainers, as we will show. Of course, if it is not binding for any agent then an increase in B will have no effect.

Since the capacity constraint is binding, $D(p,h) = B$, which pins down the price of the variety of entertainment services provided by agent i which, with $D(p,h)$ given by (5), is:

$$p_i = \Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} h_i^{\rho}. \tag{13}$$

Substituting (13) into (7), the rent captured by entertainer i is

$$m(h_i) = \Big[\Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} h_i^{\rho} - c\Big]B. \tag{14}$$

With p_i given by (13), the aggregate price, from (10), is

$$P = \Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} H_k^{\rho-1}, \tag{15}$$

where

$$H_k := \Big\{\int_k^1 h_i^{\rho}\Big\}^{\frac{1}{\rho}}. \tag{16}$$

From (15), $\Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} = PH_k^{1-\rho}$. Substituting this into (14), the rent captured by entertainer i is

$$m(h_i) = BPH_k^{1-\rho} h_i^{\rho} - Bc, \tag{17}$$

where the first term is total revenue, which we denote by $R(h_i)$, which is proportional to capacity, the general price of entertainment services, and the entertainer's human capital raised to the power ρ. The second term represents the labor costs.

Equation (15) implies that $M/(BH_k) = P^{\frac{1}{1-\rho}}/f(P,\mu)$. With $f(P,\mu) = \frac{P^{\frac{\rho-\hat{\rho}}{(1-\rho)(1-\hat{\rho})}}}{\mu^{\frac{1}{1-\hat{\rho}}} + P^{\frac{\hat{\rho}}{\hat{\rho}-1}}}$, it follows that

$$P + (\mu P)^{\frac{1}{1-\hat{\rho}}} = \frac{M}{BH_k}. \tag{18}$$

This equation and equation (17) together imply that an entertainer acquires a fraction of aggregate

[16] An exact condition for this is provided in Subsection 5.2.

income that is proportional to his human capital raised to the power ρ:

$$R(h_i) = \frac{1}{1+\mu^{\frac{1}{1-\widehat{\rho}}} P^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}} \cdot M \cdot \frac{h_i^\rho}{H_k^\rho}. \tag{19}$$

Here, the first term is the fraction of aggregate income, M, that is spent on entertainment[17]– note that for the Cobb-Douglas case, where $\widehat{\rho} = 0$, it is $1/(1+\mu)$, it is independent of the price of entertainment, P. The third term is the fraction of spending on entertainment services for agent i. Note that $\int_k^1 h_i^\rho H_k^\rho = 1$, which is proportional to h_i^ρ. This is because the price that an entertainer charges, by (13), is proportional to his human capital raised to the power ρ.

Agent k, who is indifferent between becoming an entertainer or supplying labor, is identified by the condition $m(h_k) = A$. Applying (17), for $i = k$ it follows that

$$PH_k^{1-\rho} h_k^\rho = c + \frac{A}{B}. \tag{20}$$

which corresponds to equilibrium condition (ii).

With (17), condition (iii) becomes

$$M = kA - (1-k)cB + BPH_k. \tag{21}$$

The simultaneous equations (18), (20) and (21) then pin down the equilibrium values of (P, k, M).

Canceling out M with (18) and (21) and substituting for P with the solution from (20), we have an equation that pins down k:

$$\mu^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}} = (A/B + c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}} (k - k_0), \tag{22}$$

with $k_0 = \frac{Bc}{A+Bc}$.

Since $\rho - \widehat{\rho} > 0$, $H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}}$ increases with $H_k = \{\int_k^1 h_i^\rho\}^{\frac{1}{\rho}}$, which decreases with k. Since $\rho > 0$, $h_k^{\frac{-\rho}{1-\widehat{\rho}}}$ decreases with h_k which, by assumption, increases with k. Moreover, $H_1 = 0$. Therefore, the left hand side (LHS) of (22) decreases from a positive number to 0 with k ascending from k_0 to 1. But with this movement of k, the right hand side (RHS) of (22) linearly increases from 0 to $1 - k_0 = A/(A+Bc) > 0$. Both sides are depicted in Figure 1 below.

This argument clearly shows that:

Proposition 1. *A unique equilibrium exists, for $k \in (k_0, 1)$.*

[17] From (3), the fraction of aggregate income spent on the subsistence good is $\frac{1}{1+\mu^{1/(\widehat{\rho}-1)} P^{\widehat{\rho}/(\widehat{\rho}-1)}}$. Therefore, the fraction spent on entertainment services is $1 - \frac{1}{1+\mu^{1/(\widehat{\rho}-1)} P^{\widehat{\rho}/(\widehat{\rho}-1)}} = \frac{1}{1+\mu^{\frac{1}{1-\widehat{\rho}}} P^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}}$.

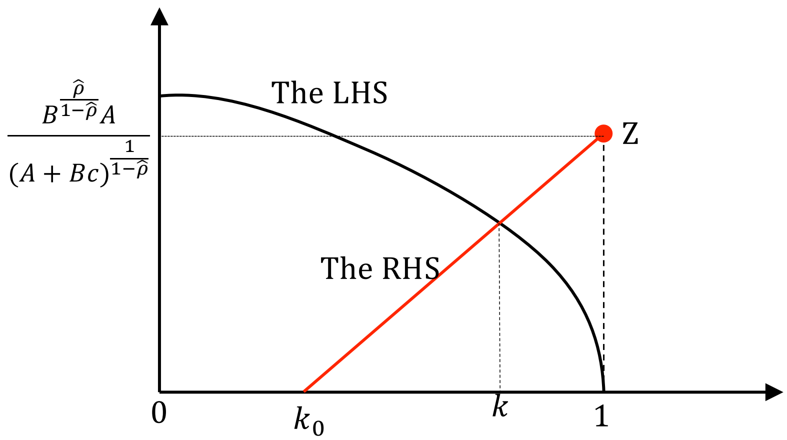

Figure 1: The Existence and Uniqueness of Equilibrium

The economic intuition for the existence and uniqueness of an equilibrium can be understood in light of the CES preference and the market forces at play. The former ensures that both the subsistence good and some entertainment services are provided in any equilibrium, such that the population is divided between these two career types – i.e., k lies between 0 and 1. Market forces then ensure the uniqueness of this division: if too many agents choose to provide labor and produce the subsistence good, then the entertainment services will be costly, which will induce entry into entertainment service provision. Conversely, if too few agents provide labor there will be entry into production of the subsistence good.

Next consider the equilibrium income distribution. Agents $i < k$ choose to provide labor and earn income A, while agents $i \geq k$ become entertainers, where their income, m_i, is related to their human capital according to (17). Substituting $PH_k^{1-\rho} = (c + A/B)h_k^{-\rho}$ – from (20) – into (17) we find that for $i \geq k$,

$$m_i = (Bc + A)\frac{h_i^\rho}{h_k^\rho} - Bc. \tag{23}$$

Entertainers' income is therefore proportional to their human capital raised to the power ρ. The overall distribution of agents' income is illustrated in the following figure.[18]

[18]The figure is based on the assumption that h_i is a convex function of i so that m_i, though a concave function of h_i, is convex in i. Roughly, the assumption is that within a typical talent distribution, there are a small number of people at the top who are much more talented than the rest – a view that seems consistent with the evidence.

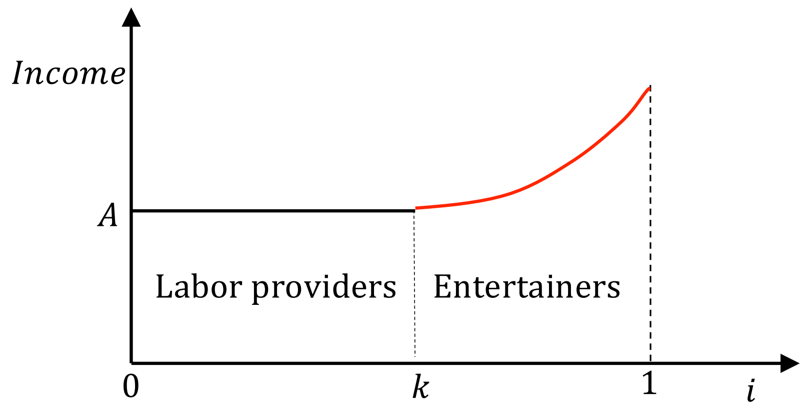

Figure 2: The Equilibrium Income Distribution

4.1. The Effects of Type-B Technological Progress

Here we consider the comparative statics with respect to B.[19] We first consider how an increase in B affects the occupational choice of the agents, captured by k. To begin with, it has no effect on the income associated with providing labor, which is fixed at A. As for the income of an entertainer, an increases in B raises their labor costs because now they need to hire more labor to maintain a larger capacity. On the revenue side, there are three conflicting effects. First, a positive effect: a rise in B enlarges the entertainers' capacity and thereby increases their revenues. Second, a negative effect: since all entertainers are equally exposed to the rise in capacity, each individual entertainer faces fiercer competition, which reduces revenues (all else equal). And third, an increase in B may affect aggregate income, positively or negatively, thereby affecting entertainers' revenues.

The equilibrium k is determined by equation (22), where the LHS is independent of B. As a result, the curve in Figure 3, representing the LHS, is invariant to an increase in B. The RHS, on the other hand, is affected in two ways. First, $k_0 = Bc/(A + Bc)$ increases with B so that k_0 moves rightward. Second, the uppermost part of the line, Z, may shift up or down. If the position of Z does not change, while k_0 moves to the right, clearly k will also move to the right, as is illustrated in the left panel of Figure 3. If Z moves down then k shifts further to the right, as is illustrated in the right panel of the Figure.

The height of Z is $(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}(1-k_0) = AB^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}/(A+Bc)^{\frac{1}{1-\widehat{\rho}}}$. Z moves down with an increase in B if

$$\frac{dAB^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}/(A+Bc)^{\frac{1}{1-\widehat{\rho}}}}{dB} \leq 0,$$

[19]Since we are examining the case in which the capacity constraint, $D(p;h) \leq B$, is binding, the comparative statics are based on the assumption that it remains binding following any change. Later we consider the comparative statics for the case in which the capacity constraint is binding for some share of entertainers.

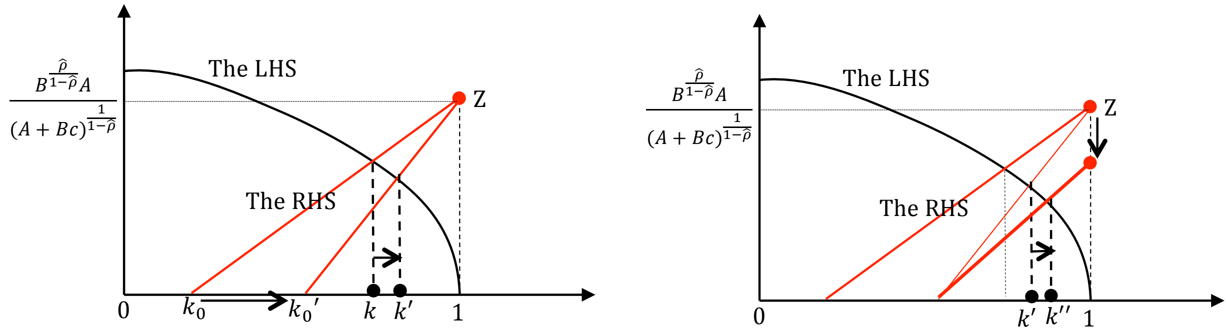

Figure 3: The effect of an increase in B on k. The left panel: an increase in B moves k_0 to k', which increases k to k'. The right panel: if point Z moves down, then k is shifts further to k''

which is equivalent to

$$c \geq \frac{\widehat{\rho}}{1-\widehat{\rho}} \cdot \frac{A}{B}. \tag{24}$$

It follows that

Proposition 2. *If* $c \geq \frac{\widehat{\rho}}{1-\widehat{\rho}} \cdot \frac{A}{B}$, *then* $dk/dB > 0$, *that is, with a rise in the limit of IRS, fewer agents choose to provide entertainment services, and the number of varieties provided falls.*

Proof. We relegate the proof to Appendix A. □

The Cobb-Douglas case ($\widehat{\rho} = 0$) provides an example in which Proposition 2 holds. In this case the fraction of aggregate income spent on entertainment is fixed at $1/(1+\mu)$ by (19). If no entertainers exit (and aggregate income does not change), then each of them now receives the same amount of revenue, but faces increased labor costs (in order to maintain the larger capacity). Thus, the previously marginal entertainer, who was indifferent between the two occupational choices, now finds it unprofitable to employ their human capital. In other words, they are squeezed out, leaving a smaller number agents to share the revenue pool and thereby increasing the revenue allocated to the remaining entertainers.

Besides having implications for the occupational choices of agents, Proposition 2 also implies that the lower end entertainers lose from an increase in B. Consider those entertainers endowed with a level of human capital close to the marginal entertainer's, and who are therefore squeezed out of the entertainment business with the increase in B. Before the rise in B they earned strictly more than the wage of labor, A, as they strictly preferred being an entertainer to providing labor. After the increase in B they are squeezed out, and subsequently provide labor, and therefore earn the wage of labor. These agents therefore lose. This result is stated as the proposition below and is formally proved.

Proposition 3. *There exists $\widehat{k} > k$ such that $dm_i/dB < 0$ for $i \leq \widehat{k}$ – namely, the lower end entertainers lose from an increase in the limit of IRS.*

Proof. We need only show that $dm_i/dB < 0$ for $i = k$. When this is the case, the Proposition follows from the fact that dm_i/dB is continuous in i. By (23), $\frac{dm_i}{dB} = h_i^\rho/h_k^\rho \cdot [c - (A+Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB}] - c$. At $i = k$, therefore, $\frac{dm_i}{dB} = c - (A + Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB} - c = -(A + Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB} < 0$ because $(\log h_k)'$ is assumed to be positive and $\frac{dk}{dB} > 0$ by Proposition 2. □

An additional effect of a rise in B is that relatively high-quality entertainers gain relatively more due to the capacity enlargement. This is because the increase in B affects an entertainer's revenue in proportion to the entertainer's human capital (raised to the power ρ). Intuitively, a higher-quality entertainer charges a higher price which, by (13), is in proportion to h_i^ρ. This result leads to the following proposition.

Proposition 4. *Under assumption (12), dm_i/dB increases with m_i. That is, the greater the current income of an entertainer, the more the entertainer gains (or the less he loses) from an increase in the limit of IRS.*

Proof. We relegate the proof to Appendix B. □

However, if the condition assumed in (12) does not hold, it may be the case that dm_i/dB decreases with m_i – that is, the greater the present income of an entertainer is, the less it gains, or the more it loses, from an increase in the limit of IRS. In Appendix C, we construct an example of this case. Intuitively, this case is driven by the third effect noted above arising from an increase in B, namely the effect that operates through aggregate income. By (19), if aggregate income changes by ΔM, other things fixed, the revenue of entertainer i changes by $\Delta R(h_i) = \frac{1}{1+\mu^{\frac{1}{1-\widehat{\rho}}} P^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}} \frac{h_i^\rho}{H_k^\rho} \cdot \Delta M$. Thus, if $\Delta M < 0$, the loss to the entertainer is proportional to his human capital, to the power ρ. If this loss outweighs the gain due to the positive effect arising from the loosening of the capacity constraint (which is the mechanism behind Proposition 3), then the net effect is that revenue falls when B rises, and the net loss is proportional to h_i^ρ. However, this case is unlikely in reality due to the fact that the economy consists of hundreds of occupations (while in the model there are only two) and any change in one occupation is unlike to have a large effect on aggregate income. That is, ΔM should be small due to any change in the limit of IRS for any particular occupation. See Appendix C for a full explication of this case.

By Proposition 4, if an entertainer's human capital is high enough the increment in revenue will outweigh the increment in cost, and the entertainer acquires a net gain from capacity enlargement. To state this formally, let

$$\Omega(\rho) := \frac{\rho \cdot h_k'/h_k}{1 + \rho \cdot h_k'/h_k \cdot (k - k_0)}.$$

By assumption (12), $\Omega(\rho) \cdot A/(A+Bc) < 1$.[20] We can then state the following:

Lemma 1. *$dm_i/dB > 0$, namely agent i's income rises with an increase in the limit of IRS, if*

$$\frac{h_i^\rho}{h_k^\rho} > \frac{1}{1 - \Omega(\rho) \cdot A/(A+Bc)}. \tag{25}$$

Proof. We relegate the proof to Appendix D. □

Condition (25), however, is not easy to check. This is because k is determined in equilibrium and depends on the distribution of human capital (specifically, the functional form of $h(i)$). Below, we present an approach, dispensing with k, to get a condition under which the top entertainers gain on net from an increase in the limit of IRS.

Let $f(k_0, y)$ denote the unique solution for $t \in [k_0, 1]$ in

$$t - k_0 = y(1-t)^{\frac{\rho - \widehat{\rho}}{\rho(1-\widehat{\rho})}},$$

and let

$$D := \mu^{\frac{1}{1-\widehat{\rho}}}(A/B + c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}.$$

Lemma 2. *Assume $h_1 > 1$. If $h_1 \geq \zeta \cdot h(f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}}))$, then $h_1 > \zeta \cdot h_k$.*

Proof. We relegate the proof to Appendix E. □

The two lemmas above lead to the following proposition, which gives a condition for the distribution function of human capital under which the top entertainers' income strictly increases with B. Let

$$\xi := [\frac{1}{1 - \Omega(\rho) \cdot A/(A+Bc)}]^{\frac{1}{\rho}}.$$

Proposition 5. *If $h_1 > 1$ and $h_1 \geq \xi \cdot h(f(k_0, D \cdot \xi^{\frac{\rho}{1-\widehat{\rho}}}))$, then $dm_1/dB > 0$, i.e., the top entertainers gain on net from an increased limit of IRS.*

This proposition, together with Proposition 2 which states that entertainers at the bottom of the distribution are pushed out of the entertainment occupation into providing unskilled labor, implies that an increase in B causes the change in the income distribution depicted in Figure 4.

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[20] Given k, $\Omega(\rho)$ increases with ρ. Therefore, $\Omega(\rho) \leq \Omega(1) = \frac{h'_k/h_k}{1 + h'_k/h_k \cdot (k - k_0)}$, which by the assumption is smaller than $\frac{A+Bc}{A}$.

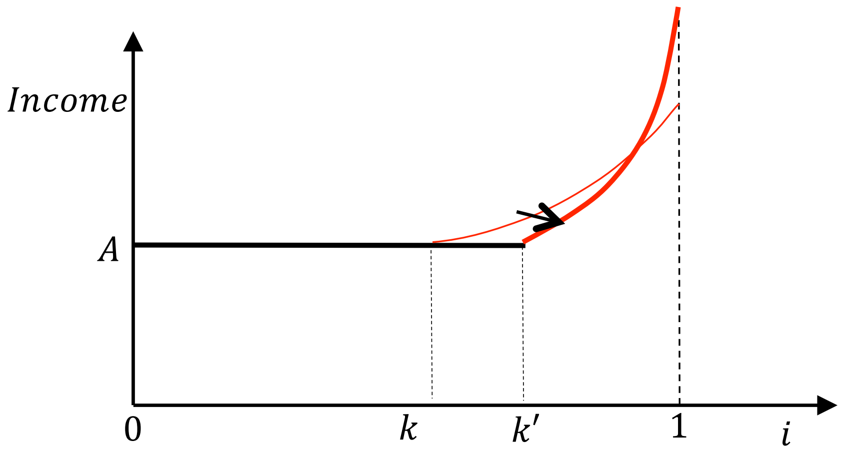

Figure 4: An increase in B squeezes the lower-end entertainers out, and raises the income of the upper-end entertainers.

4.2. The Effects of Type-A Technological Progress

We now consider the comparative statics with respect to A, the productivity of labor. We start by considering how an increase in A affects the agents' occupational choices. First, a rise in A directly increases the income of labor. This effect alone would induce more agents to provide labor and fewer to become entertainers. However, this direct effect is countered by an indirect effect. By increasing aggregate income, an increase in A will raise the demand for entertainment, which induces more agents to become entertainers and fewer to provide labor. The balance between these two forces determines shifts in k, reflecting the number of agents in the entertainment occupation. Below we show that if the condition for Proposition 2 – namely, (24) – holds, then the indirect income effect dominates the direct effect and more agents become entertainers (i.e., k falls).

To show this graphically, we return to equation (22), which determines equilibrium k. The two sides of the equation are depicted in Figure 5. The LHS, represented by the curve, is independent of A. Therefore, the curve in Figure 5 does not shift with an increase in A. As for the RHS, an increase in A shifts the straight line in Figure 5 in two ways. First, $k_0 = Bc/(A+Bc)$ falls with an increase in A and the position of k_0 shifts leftward. Second, the uppermost part of the line, Z, may move up or down. If the position of Z does not change, but k_0 moves leftward, then so does k, as is illustrated by the left panel of the Figure. If Z moves upward, then k falls further, as is illustrated by the right panel of the Figure.

The height of Z is $(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}(1-k_0) = AB^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}/(A+Bc)^{\frac{1}{1-\widehat{\rho}}}$. Z moves upward with an increase in A if

$$\frac{dAB^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}/(A+Bc)^{\frac{1}{1-\widehat{\rho}}}}{dA} \geq 0,$$

which is equivalent to (24). Therefore,

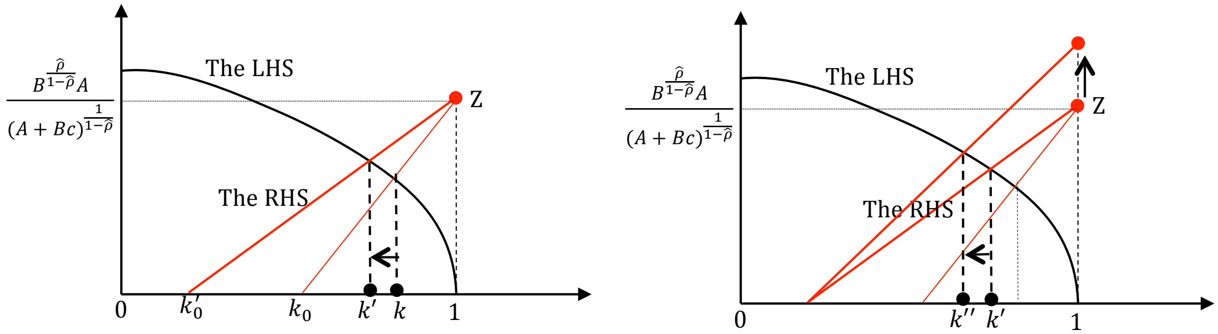

Figure 5: The effect of an increase in A on k. The left panel: an increase in A moves k_0 to the left, which decreases k to k'. The right panel: if Z moves upward, then k falls further to k''

Proposition 6. *If* $c \geq \frac{\widehat{\rho}}{1-\widehat{\rho}} \cdot A/B$ *– i.e., (24) holds – then* $dk/dA < 0$*. Thus, with a rise in the productivity of labor, more agents choose to provide entertainment services, and the number of varieties therefore increases.*

Proof. We relegate the proof to Appendix F. □

Again we use the Cobb-Douglas case (where $\widehat{\rho} = 0$) for intuition. If A increases by one percent, then labor's income increases by the same amount. If entertainers' income also increases by one percent – so that k is unmoved – then aggregate income also increases by one percent. In the Cobb-Douglas case a fixed fraction of this rise in income goes to entertainers. As a result, each entertainers' revenue, in particular the marginal entertainers', increases by one percent, while their (labor) costs stay the same, equal to Bc. Therefore, the marginal entertainers' income increases by more than one percent, i.e., more than the increment of the labor suppliers' income. By (18) and (21), if $\widehat{\rho} = 0$ (i.e. the Cobb-Douglas case), aggregate income $M = \frac{1+\mu}{\mu}[kA - (1-k)Bc]$. Therefore, if k does not decrease, then a one percent increase in A induces M to increase by more than one percent. Thus, the marginal entertainer now strictly prefers becoming an entertainer. This implies that someone with lower human capital enters the entertainment occupation – i.e., k goes down.

Note that an increase in A directly benefits unskilled labor, but this is not the case for entertainers. From (2), the marginal cost of production is $w \cdot c/A = c$, independent of A. It is in this sense that we can say that *an increase in A is biased toward (low-skill) labor.* However, the argument above suggests that all entertainers gain more from an increase in A than laborers, due to general equilibrium effects. This is strictly proved in the following proposition.

Proposition 7. *For* $i \geq k$, $\frac{dm_i}{dA} > 1$ *and* $\frac{dm_i}{dA}$ *increases with* m_i.

Proof. By (23), $\frac{dm_i}{dA} = \frac{h_i^\rho}{h_k^\rho} + (Bc+A)(-\rho)\frac{h_i^\rho}{h_k^{\rho+1}} \cdot h_k' \cdot \frac{dk}{dA} = \frac{h_i^\rho}{h_k^\rho} \cdot [1 + (Bc+A)(\log h_k)' \cdot (-\rho\frac{dk}{dA})]|_{-\rho\frac{dk}{dA}>0 \text{ (by Prop. 5)}} >$

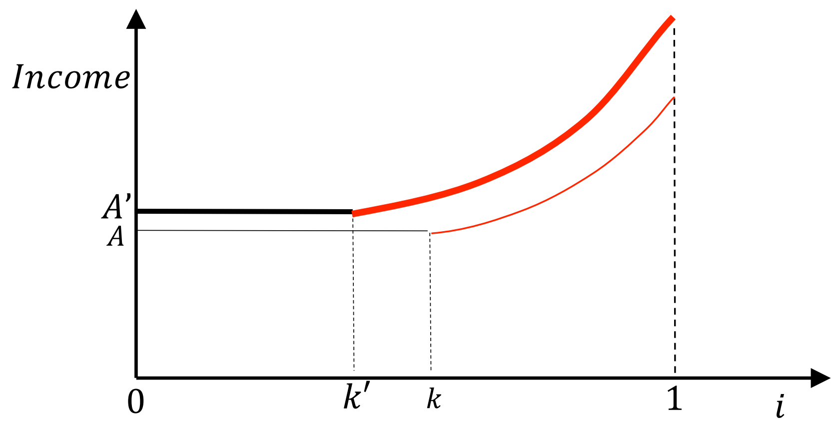

Figure 6: An increase in A raises all agents' incomes while also increasing income inequality.

$\frac{h_i^\rho}{h_k^\rho} \geq 1$. Moreover, by (23), $\frac{h_i^\rho}{h_k^\rho} = \frac{m_i+Bc}{A+Bc}$. Then, $\frac{dm_i}{dA} = \frac{m_i+Bc}{A+Bc} \cdot [1 + (Bc + A)(\log h_k)' \cdot (-\rho\frac{dk}{dA})]$ and increases with m_i. □

The proposition is driven by two effects generated by an increase in A. One is the effect on occupational choice, as shown in Proposition 6. This effect ensures that the marginal entertainer gains more from the increase than does labor. The other effect is due to the change in aggregate income, which increases with a rise in A. The fraction of this increase that an entertainer acquires is in proportion to his human capital (to the power ρ) – by (19), $\Delta R(h_i) = \frac{1}{1+\mu^{\frac{1}{1-\hat{\rho}}} P^{\frac{\hat{\rho}}{1-\hat{\rho}}}} \frac{h_i^\rho}{H_k^\rho} \cdot \Delta M$, proportional to h_i^ρ – and therefore in proportion to his earnings.

The proposition states that the more an entertainer currently earns, the greater is the growth in his income from an increase in A. Intuitively, when the economy becomes richer, agents spend more on entertainment services. This rise in spending is allocated more toward more expensive entertainment, which is provided by more talented entertainers who therefore earn even more.

Therefore, a rise in the productivity of unskilled labor both directly benefits the lowest income workers while simultaneously increasing income inequality. The effect on the income distribution is illustrated in Figure 6.

4.3. Discussion

When the Capacity Constraint Is Non-Binding for Some Entertainers

If the capacity constraint is non-binding for some entertainers, then these entertainers' human capital will lie at the lower end of the distribution. The demand for an entertainer's services, by (5), is proportional to $h_i^{\rho/(1-\rho)}$. Thus, the profit-maximizing output in the absence of the capacity constraint increases with h_i. As a result, if it is binding for agent i then it is binding for all the agents $i' \geq i$, and if it is not binding for agent i, then neither is it for any agent $i' \leq i$. Thus, if and only if the capacity constraint is binding for the marginal agent k, will it bind for all entertainers. Since the entertainers' problem is given by (7), in the absence of a capacity constraint, the optimal price is c/ρ. The constraint is binding for agent k if he cannot reach this price by supplying enough output, namely if the price pinned down by the binding capacity constraint, p_k, is no less than c/ρ. This condition, with p_k given by (13) with $i = k$, formally is:

$$\Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} h_k^{\rho} \geq \frac{c}{\rho}. \tag{26}$$

If the capacity constraint is binding for some share of entertainers and non-binding for the remainder, the argument above implies that there exists $j \in (k, 1)$ such that it is non-binding for $i < j$ and binding for $i > j$. In particular, it is non-binding for the marginal entertainer, k. In this case, the propositions derived above all hold qualitatively.

Proposition 1 still holds. The unique equilibrium still exists, and is driven by the same economic forces as before. If too many agents choose to provide labor and produce the subsistence good, then the entertainment services will be expensive, which will induce further entry. Conversely, if too few agents provide labor there will be entry into production of the subsistence good.

Proposition 2 still holds, and therefore so does Proposition 3 which is driven by Proposition 2; that is, an increase in B squeezes the entertainers at the lower end out of the profession (i.e., $dk/dB > 0$). In fact, this holds even under a less strict condition. Specifically, the marginal entertainer, now with a non-binding capacity constraint even before the increase in B, gains nothing from this increase. Therefore, the positive effect due to the loosening of the capacity constraint is now absent. As a result, there is now an additional reason that he is adversely affected by the increase and squeezed out of the entertainment occupation.

Propositions 4 and 5 hold qualitatively, that is, the entertainers currently earning more will gain more or lose less from an increase in B, and the top entertainer, if his human capital is high enough, gains on net from this increase. Both propositions are driven by the fact that entertainers with higher human capital – who therefore earn more – gain more from a capacity enlargement, again due to the fact that they are able to charge higher prices which, by (13), are in proportion to their human capital (to the power ρ). But the exact conditions for these two propositions will change since M, P and k will be ruled by a different profile of equilibrium conditions.

Proposition 6 holds qualitatively – namely, an increase in A induces more agents to live on human capital – though the exact condition may change. Consider the Cobb-Douglas case. A one percent increase in A raises labor's income by the same amount. Suppose that this affects all entertainers in the same way, so that k is unmoved. Then aggregate income rises by one percent, which means the revenue of the marginal entertainer increases by the same amount. But his labor cost stays the same. As a result, his income rises by more than one percent, thus making the marginal entertainer strictly prefer the entertainment business and thus inducing entry into entertainment. This intuitive argument suggests that a one percent increase in A moves k leftward.

Proposition 7 still holds, namely more talented (and thus richer) entertainers gain more from an increase in A. Again it is driven by the same effect: an increase in A affects entertainers' income by raising aggregate income, and the fraction of this increase that an entertainer acquires is in proportion to his human capital level (to the power ρ).

Unaffected Occupations

The model thus far assumes that there is only one type of human capital, which is used to provide entertainment services. In reality, there are many types of human capital associated with many types of occupations. Moreover, as we argued in the Introduction, recent ICT innovations have led to a rise in the limit of IRS for some occupations, while for others these innovations have had little impact. This subsection examines how the increase in the limit of IRS for one occupation, which we refer to as the "affected" occupation, may impact another occupation, for which the limit of IRS is unchanged, and which we refer to as the "unaffected" occupation.

Suppose that, in addition to the continuum of agents previously described, there is now another continuum of agents, $j \in [0,1]$. Agent j has one unit of labor and $\widetilde{h}_j$ of another type of human capital which is needed for childcare services (e.g., patience or tolerance of noise). Thus, each agent j makes an occupational choice between labor and childcare. The provision of childcare is subject to IRS up to limit $\widetilde{B}$:

$$y = \left\{ \begin{array}{c} \frac{A}{\widetilde{c}} L \text{ if } L \le \frac{\widetilde{c}}{A}\widetilde{B} \\ \widetilde{B} \text{ if } L > \frac{\widetilde{c}}{A}\widetilde{B} \end{array} \right\}.$$

Each agents' utility is given by

$$\left(\mu s^{\widehat{\rho}} + \big(\int_E (h_i e_i)^{\rho} \big)^{\widehat{\rho}/\rho} + \big(\int_F (\widetilde{h}_j f_j)^{\widetilde{\rho}} \big)^{\widehat{\rho}/\widetilde{\rho}} \right)^{1/\widehat{\rho}},$$

where f_j is the consumption of the variety of childcare services provided by agent j and e_i is consumption of a variety of entertainment services as before.

What will be the effect of an increase in B (the limit of IRS for entertainers) on the childcare workers' incomes? It is straightforward to carry out the formal analysis for this extended model, but instead we only provide the intuition here. An increase in B affects childcare workers in the following two ways.

1. A price effect: entertainment services become relatively cheaper. As is typical in a consumers'

decision problem, the price reduction generates two conflicting effects on the spending of each agent on childcare: a negative substitution effect and a positive income effect. For the CES case that we are considering, if $\widehat{\rho}$ is positive, that is, if entertainment and childcare are substitutes in consumption, then the negative substitution effect dominates the positive income effect and childcare workers are adversely affected. If $\widehat{\rho}$ equals zero (the Cobb-Douglas case), then these two effects exactly offset each other and childcare workers are not affected. Finally, the net effect will be positive if the services provided by the unaffected occupation and those by the affected occupation are complements ($\widehat{\rho} < 0$).[21]

2. An aggregate income effect: aggregate income may increase or decrease with the increase in B, which may then affect childcare workers positively or negatively.

In addition, we can derive a parallel formula to (19): a childcare worker with higher human capital acquires a greater share of aggregate spending on childcare.

Finally, note that if B is unchanged then there is no "affected occupation". In this case, childcare workers and entertainers are symmetric. Therefore, an increase in A affects both occupations in the same way as explained above.

5. Empirical Patterns

In this section we bring the comparative statics results from Section 4 to the data. We discuss two contexts in which the model's mechanisms are consistent with the evidence, noting at the same time that the mechanisms may not be relevant for all countries at all times. We first discuss evidence on the relationship between economic growth and income inequality in developing countries over the past two decades, with a particular focus on China. We then bring in new evidence on the structural shift in the Chinese economy toward the services sector and we show that together these facts are consistent with an increase in type A technological change. Finally, we exploit U.S. occupational data over the same time period, providing econometric evidence in favor of the mechanisms generated by our type B technological change.

5.1. Evidence on Type A Technological Progress

Over the past several decades many developing countries have followed a growth trajectory characterized by rising incomes for the poorest individuals accompanied by rising inequality across the overall income distribution. These trends almost always coincide with a shift toward greater relative provision of services, a set of occupations in which workers typically perform very similar tasks –

[21] By (3), if the price of entertainment services, P, decreases, the fraction spent on the subsistence good, $\frac{1}{1+\mu^{1/(\widehat{\rho}-1)}P^{\widehat{\rho}/(\widehat{\rho}-1)}}$, decreases too, unless $\widehat{\rho} \leq 0$ (but we assume $\widehat{\rho} \geq 0$ – namely, that the subsistence good and services are substitutes).

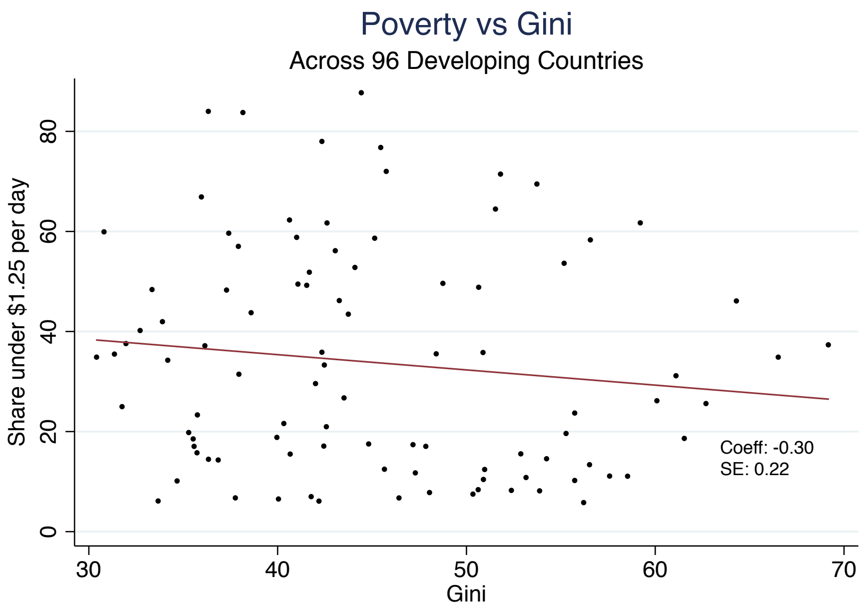

Figure 7: Poverty and Inequality. Source: United Nations

e.g., computer repair, hair styling, food preparation, acting – and apply their human capital in a competitive market for their differentiated output. Here we argue that the type A technological change described above provides a simple and intuitive explanation for each of these key features of the economic development process.

Focusing first on the relationship between the absolute income of the poorest workers and the overall income distribution, we note that the level of poverty and the level of income inequality within developing countries over the past 20 years are negatively correlated.[22] Figure 7 documents the within-country conditional correlation between the share of the workforce living on less than \$1.25 per day and the Gini coefficient for the 96 least developed countries over the period 1995-2010,[23] where we see that indeed there is a negative slope. The most well-known explanation for this relationship, reflected in the so-called Kuznets curve, focuses on the migration of cheap labor from rural areas to the cities in response to improving economic opportunities, a transition that keeps low-skill wages from rising in the cities and simultaneously generates profits for capital owners, a supply-side channel that leads to increasing inequality. While this mechanism is undoubtedly important, our model provides a complementary and intuitive demand-side mechanism linking rising incomes of the poorest laborers with rising inequality.

To reiterate, in the model rising incomes at the bottom of the income distribution lead to an

[22]Across all countries (not just developing ones) the relationship we document here is more ambiguous, see for instance Fields (2002). Another prominent exception is the experience of the Asian Tiger group of countries whose rapid development coincided with an overall decline in income inequality.

[23]More specifically, we plot the correlation between the Gini coefficient and those living below \$1.25, where country fixed effects are "partialed out".

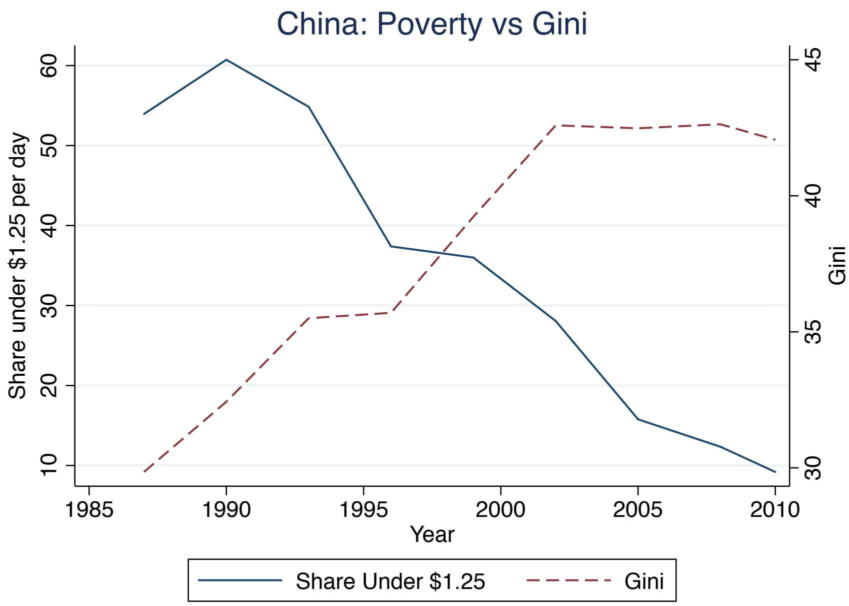

Figure 8: Poverty and Inequality in China. Source: United Nations

increase in the demand for goods and services. In general equilibrium this leads to a rise in income for all producers of goods and services, but a relatively greater increase for the workers with the most human capital (who work in occupations subject to IRSL and monopolistic competition). Focusing now on China, Figure 8 denotes the relationship between the incomes of the poorest and overall inequality over the past two decades, where we see both a decline in poverty and a simultaneous rise in inequality, similar to Figure 7. As noted above, this fact is consistent both with our mechanism as well as the more standard rural-to-urban migration story. However, a further prediction of our model is that the career choice margin will adjust as well, as marginal workers shift out of the provision of pure labor into a labor market in which workers' relative talent (or human capital) determines their income, and in which workers within a given occupation perform relatively similar tasks. Crucially, this facet of the model fits the observed structural change from labor-intensive production to services provision that is a key step in the economic development process. For instance, Figure 9 documents Chinese employment growth by sector over the period from 1987 to 2002, where we focus on the pre-Internet period in order to avoid the effects due to type B technological change, which we discuss in the next section.[24] In the Figure we see evidence of the structural shift in the form of rising employment shares for workers employed in Retail and Other Services occupations, with positive employment growth in Finance, Insurance and Real Estate as

[24]In 2003 only six percent of Chinese had access to the Internet.

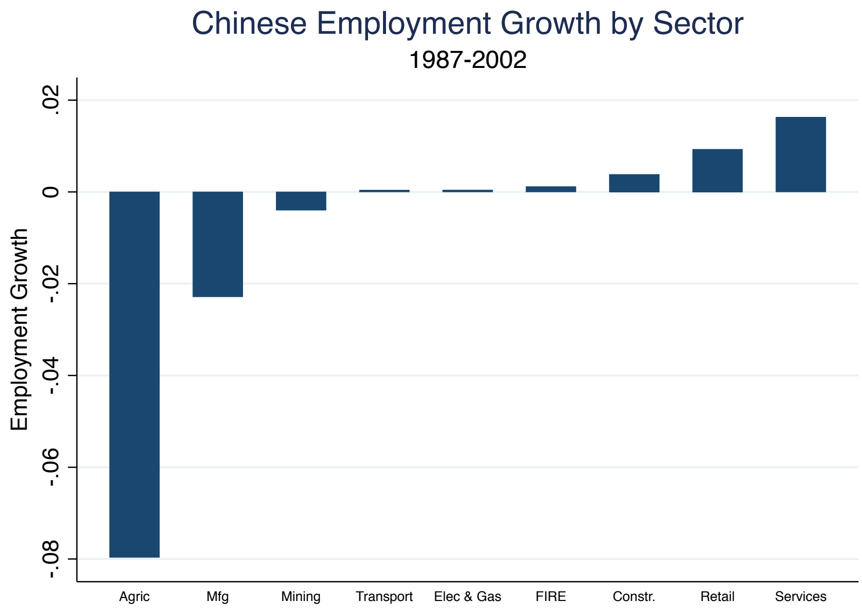

Figure 9: Percentage Point Change in the Chinese Employment Share. Source: United Nations

well.[25]

Whereas the typical narrative ascribes rising inequality within developing countries to the gains reaped by capital owners, our channel attributes it to rising earnings generated by competitive forces within occupations subject to IRSL and monopolistic competition, which we believe is a reasonable characterization of many service occupations. Capital has clearly generated large returns for many Chinese investors, but there is strong evidence that rising inequality has also been due to increased wage earnings, particularly within services occupations. For instance, over the period 1988 to 2002 the real income share of the most highly paid services occupations rose substantially: for Managers the income share went from 6.72 percent to 11.21 percent while the share accruing to Professionals and Technicians rose from 16.31 to 22.48 percent. More generally, over a period in which the economy was shifting toward increased services provision the earnings of the lowest skilled workers were virtually unchanged while the earnings of college graduates increased over 300 percent (see Deng and Li (2009)).

These facts are in line with the model's predictions and, again, come about via a theoretical framework in which rising incomes for the poorest workers leads to increased inequality, facts that are also consistent with the growth experience of many developing economies.

[25]Further in support of this shift: over the period 1988 to 2002 the share of real income accruing to workers in Education, Culture and the Arts rose from 7.45 percent to 9.58 percent and the share accruing to Finance and Insurance rose from 1.57 to 2.82 percent. See Deng and Li (2009)

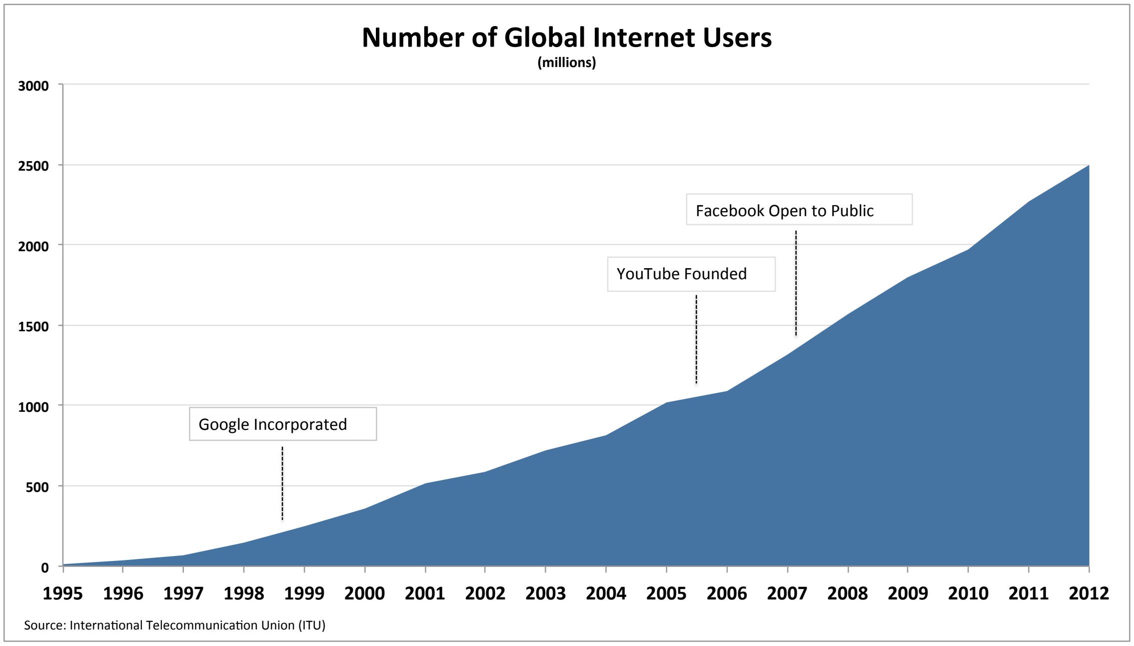

Figure 10: Growth in Global Internet Access

5.2. Evidence on Type B Technological Progress

Type B technological change is most easily investigated in a developed country context, and so in this section we shift to an analysis of U.S. data. Specifically, we investigate whether the recent growth in U.S. inequality can in part be attributed to the interaction of distinct occupational features with new information and communication technologies (ICT) – specifically, the Internet – as our type B technological change predicts. Throughout, we exploit data on wages and employment within U.S. occupations from the U.S. Current Population Survey (CPS) over the years 1985 to 2006.[26]

In the model, B represents the limit of IRS for an occupation, reflecting the scale of operation of the workers in the occupation. Differences in the scale of operation across occupations and over time may arise for many reasons; here we argue that an important difference arises due to the rapid expansion of the Internet beginning in the mid-1990s, which differentially affects the scale of operation for different occupations. For instance, with the expansion of the Internet musicians and online retailers can sell to more customers, whereas the number of customers that a barber or dentist can sell to remains effectively unchanged. Among the many reasons that the magnitude of the effect will differ across occupations are the fact that occupation output may be more or less easily digitized and, therefore, transmitted electronically, or that language may be a key determinant of demand for the occupation output, limiting demand to markets that share the language – e.g., marketing occupations.[27]

[26]The data were obtained from IPUMS (see Ruggles, Alexander, Genadek, Goeken, Schroeder and Sobek (2010))

[27]In the model each professional sells to all agents and each agent buys from all professionals. This is a result of

1	Financial services sales occupations	317	Batch food makers
2	Motion picture projectionists	318	Miners
3	Cabinetmakers and bench carpenters	319	Dental assistants
4	Editors and reporters	320	Pest control occupations
5	Furniture and wood finishers	321	Managers of medicine and health occupations
6	Typesetters and Compositors	322	Primary school teachers
7	Other financial specialists	323	Mail carriers for postal service
8	Broadcast equipment operators	324	Postal clerks, excluding mail carriers
9	Computer Software Developers	325	Special education teachers
10	Actors, directors, producers	326	Secondary school teachers
11	Nail and tacking machine operators	327	Legislators
12	Upholsterers	328	Clergy and religious workers
13	Advertising and related sales jobs	329	Inspectors of agricultural products
14	News vendors	330	Welfare service aides
15	Industrial Engineers	331	Postmasters and mail superintendents
16	Designers	332	Meter readers
17	Sawing machine operators and sawyers	333	Mail and paper handlers
18	Proofreaders	334	Hotel clerks
19	Writers and authors	335	Judges
20	Supervisors and proprietors of sales jobs	336	Sheriffs, bailiffs, correctional institution officers

Table 1: Top and Bottom 20 Occupations by Internet Exposure

Formally, we construct a measure of the extent to which the output of each of 341 U.S. occupations generated Internet sales over the period 1985 to 2006, which clearly includes the period over which the Internet has become widely accessible – approximately 1995 on, see Figure 10 – as well as the decade prior to this period, which will allow us to partially control for potential confounding factors. Since this measure reflects the component of the limit of IRS that is due to the Internet, we refer to it as B^{Int}, and we define it in the following way:

$$B_{it}^{Int} = \sum_j \left(IntShr_{jt} \times OccShr_{ijt}\right) \tag{27}$$

where $IntShr_{jt}$ is the share of industry j sales in year t that was made over the Internet and $OccShr_{ijt}$ is the share of occupation i's total hours employed in industry j in year t. Thus, the latter term reflects the importance of each industry, in terms of labor hours, to each occupation, while the former term captures the extent to which firms within each industry sell their output over the Internet.[28] Of course, the measure may not perfectly capture the extent to which occupational services are linked to Internet sales. For instance, even within an industry that sells a substantial amount over the Internet, some occupations may be specialized in brick-and-mortar sales, while others are focused on Internet sales. Here we assume each occupation's output is allocated according the share of sales that occur over the Internet within an industry. Furthermore, our analysis below will focus on the implications for wages, but the elasticity of occupational wages to Internet sales

the fact that in the model consumers are homogenous, with identical utility functions. In reality, no musician sells to the entire population (with the possible exception of Michael Jackson in 1982) and no one buys music from all musicians. But if we aggregate the consumption of all music and imagine that it is consumed by one "representative agent", then the model makes sense in terms of tracking aggregate demand for each musician.

[28]Internet sales by industry come from Census' E-Stats database, available at http://www.census.gov/econ/estats/. See Appendix G for details regarding the construction of the measure.

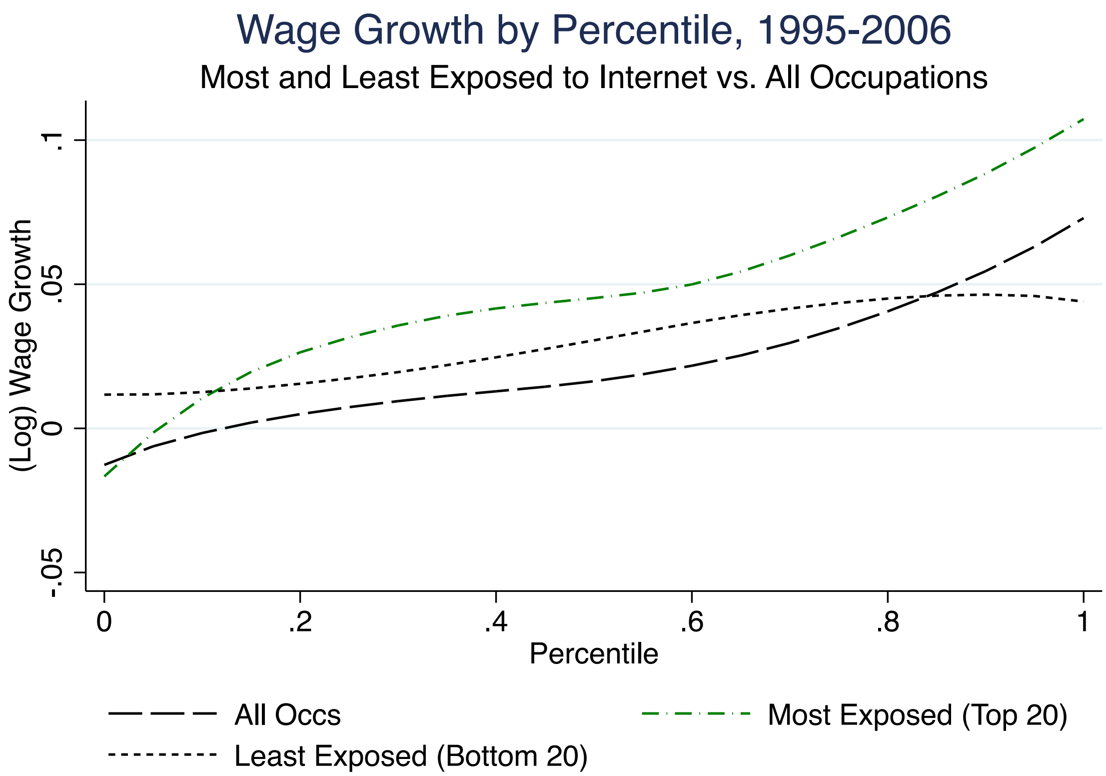

Figure 11: Wage Growth Across the Wage Distribution, Most and Least Affected by the Internet

may vary across occupations for many reasons, from which we abstract. Nevertheless, we believe the measure is a reasonable one, and captures well the differential extent to which the market for occupational services grew over the period due to the expansion of the Internet. Table 1 lists the top 20 (left column) and bottom 20 (right column) occupations in terms of their exposure to the Internet according to this measure, where the measure itself ranges from 0 (completely unexposed) to 0.28 (most exposed).

5.3. IRS, the Internet and Wage Inequality

We first focus on the prediction of the model reflected in Propositions 3 and 4, namely that increases in the parameter B – which we interpret as the global growth in Internet access and which, according to the model, will induce increases in the limit of IRS for Internet-affected occupations – will generate rising inequality across the talent (wage) distribution within these occupations, via both a net gain in earnings for the most talented (highest earners) and a net loss in earnings for the least talented (lowest earners). To more formally test Propositions 3 and 4 we first "clean" the log wage of demographic (gender, race), educational attainment, and experience (age, age squared) in a first-stage regression in order to focus as much as possible on wage variation that arises due to the intrinsic features of the occupations, rather than changes in the composition of the workforce. In addition, to the extent that the Internet led to greater IRS due to industry-specific, time-invariant features, rather than occupation features, we would like to remove this variation, and we do so by including industry fixed effects in the first stage. The residuals from this regression serve as the relevant wage variation going forward.[29]

Figure 11 provides some initial evidence in support of the Propositions. We compare log (cleaned) wage growth from 1995 to 2006 across the wage distribution (defined at the beginning of the period) for the most and least Internet-affected occupations according to (27). The most affected workers, those in the top 20 most affected occupations, clearly experienced wage losses at the lower end and wage gains at the top, in contrast to the least affected for whom wage growth was relatively constant across the distribution.[30]

As a more formal test, we estimate the following baseline regression specification:

$$\triangle Wage_{qi,t:t+1} = c + \beta_1 \triangle B^{Int}_{it:t+1} + \beta_2 Wage_{qit} + \beta_3 \left(\triangle B^{Int}_{it:t+1} \times Wage_{qit}\right) + \sigma_i t + \delta_i + \alpha_t + \epsilon_{qit} \quad (28)$$

where $\triangle Wage_{qit}$ is the annual change in the log wage in an occupation i at wage vigintile (20-quantile) q in year t, $\triangle B^{Int}_{it}$ is the regressor of interest described previously in annual changes, and $\sigma_i t$ are linear occupation-specific trends.[31] Finally, δ_i and α_t are occupation and year fixed effects and ϵ_{qit} is a disturbance term. Note that the inclusion of occupation fixed effects implies that we focus narrowly on the differential inequality growth within occupations over the period. Moreover, the occupation-specific trends will control for the common component of wage growth across percentiles within an occupation over the pre- and post-Internet periods. These may be important if, for instance, occupations with rising average wages were the most likely to invest in Internet technologies, a plausible scenario. To reiterate, the model in Section 3 predicts that occupations most exposed to the Internet will see the largest increases in inequality – i.e., the model predicts that $\beta_3 > 0$.

This identification strategy leaves open the possibility that there are omitted variables that will bias our estimates of β_3. Most problematic are those that are both correlated with the intensity of Internet sales across occupations while also directly increasing wage inequality in those occupations for reasons outside the model. In particular, the rapid fall in the price of computing technologies over the period, which were differentially adopted across industries and occupations while also facilitating access to the Internet, may have directly increased wage inequality within affected occupations, independent of any effect via access to the Internet. In this case, our estimates will be

[29] Note that we deal with top-coding in the CPS by following the method described in Bakija, Cole and Heim (2010). We also perform all the regressions with the highest earners removed, finding nearly identical results.

[30] The same pattern holds for slightly larger or smaller sets of occupations – e.g., the top 15 or 25.

[31] We tried specifications that included quadratic and cubic trends, which have little additional explanatory power. The results are also qualitatively invariant to defining the distribution with more or fewer quantiles. Results are available upon request.

Table 2: Differential Wage Impact Due to Internet Exposure

	(1) Wage Growth	(2) Wage Growth	(3) Wage Growth	(4) Wage Growth	(5) Wage Growth
Internet Exposure	0.0291	0.00807	0.00206	0.0134	0.113
	(0.0683)	(0.0594)	(0.0608)	(0.0606)	(0.127)
Base Wage		-0.0867***	-0.0871***	-0.0824***	-0.0822***
		(0.00428)	(0.00429)	(0.00425)	(0.00483)
Base Wage x Internet Exp		0.565***	0.520**	0.449**	0.391
		(0.218)	(0.218)	(0.226)	(0.429)
Occ Trend			-0.000***		
			(0.000)		
Computer Exp, 85-94				0.011***	
				(0.00364)	
Computer Exp, All Years					0.0218
					(0.015)
Observations	144647	144647	144647	138503	75129
Occ FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses are clustered at the occupation level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

biased upward – i.e., we will over-estimate the differential impact of the Internet on our occupation groups.

Unfortunately, any attempt to control for contemporaneous computer use will be hampered by the fact that much of the variation we are interested in – i.e., the variation due to occupation-specific sales over the Internet – will be highly correlated with computer use itself. As a result, we present two specifications that attempt to control for variation in computer use across and within occupations. First, in our preferred specification we control for occupation-specific computer use in the years just prior to the Internet period, from 1989 to 1994, using data from the CPS computer use supplements.[32] Our measure is the share of hours worked in an occupation by workers who use a computer. By focusing on the pre-Internet period only, we exploit variation in computer use that is unrelated to the Internet but can potentially explain future wage inequality growth. In our second specification we simply control for computer use throughout the period.

Table 2 column (2) presents the results of our primary specification, after which we progressively add occupation-specific trends (column (3)), controls for pre-Internet computer use (column (4)) and computer use in all years (column (5)). The results provide fairly strong evidence that wage inequality growth was greater in occupations whose services were more likely to be sold over the

[32]This survey asks respondents whether they "directly use a computer at work". The data source is again Ruggles et al. (2010).

Table 3: Differential Employment Impact Due to Internet Exposure

	(1) Emp Growth	(2) Emp Growth	(3) Emp Growth	(4) Emp Growth
Internet Exposure	-0.369	-0.369	-0.495	-0.405
	(0.348)	(0.348)	(0.358)	(0.332)
Occ Trend		-0.000*	-0.000	-0.000
		(0.000)	(0.000)	(0.000)
Computer Exp, 85-94			-0.001	
			(0.003)	
Computer Exp, All Years				0.001
				(0.005)
Observations	9061	9061	8347	4610
Year FE	Yes	Yes	Yes	Yes

Standard errors in parentheses are clustered at the occupation level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Internet, with all specifications generating significant, positive coefficients on the interaction term, except the final specification. Column (1), which excludes the interaction term, only provides weak evidence that wage growth was on average larger in Internet-exposed occupations, suggesting that the primary effect of the Internet was to widen inequality within occupations, with little effect on the mean wage. This is consistent with the model, which predicts relatively large wage gains for the winners (Proposition 4) and wage losses for those at the bottom (Proposition 3).

The estimates in columns (4) and (5) are consistent with our hypothesis that variation in computer use across industries is to some extent co-linear with Internet exposure in our sample. Specifically, when controlling for computer use throughout the period the impact of Internet sales on wage inequality is diminished, and not significant. Nevertheless, the positive coefficient is suggestive of an impact of Internet exposure above and beyond that which occurs directly via the use of computers within an occupation, suggesting that it is not *only* occupational computer use that is driving the estimated inequality trends indicated in Table 2.

As a test of Proposition 2, which states that an expansion in B will reduce employment within affected occupations, Table 3 presents the results of a similar, but simpler, set of regressions in which now annual employment growth in an occupation is the dependent variable. To construct the employment growth measure we again "clean" the variation in log employment of demographic, education and industry-specific variation and then take the difference across years. Formally, we estimate:

$$\triangle Emp_{i,t:t+1} = c + \tau_1 \triangle B_{it}^{Int} + \gamma_i t + \alpha_t + \epsilon_{it} \tag{29}$$

where the regressors are as described above and due to the first-differencing we are again focused on within-occupation variation. Table 2 presents the results, where column (2) adds occupation-specific trends and columns (3) and (4) add the controls for computer use within an occupation. The estimates are negative in all cases, as the model predicts, but are not significant. Overall we take this as mild evidence that Internet-affected occupations shrunk relative to other occupations during the Internet period, consistent with Proposition 2.

Finally, since year-to-year variation in hours worked and wages can be noisy within the CPS at the occupation level, in Appendix H we present the results of regressions that are identical to (28) and (29) except they are estimated in long differences. The estimated effects are qualitatively the same, and much more precise.

6. Concluding Remarks

We have developed a model incorporating two types of technological changes, and considered the consequences of each type for the income distribution and level of employment both across and within occupations. The model's mechanisms are unique in two primary ways. First, although type A technological change is unskilled-biased, it widens income inequality due to the fact that one of its main effects is to increase aggregate income, and a greater fraction of this increase is captured by agents with higher human capital endowments. This mechanism may be partly responsible for the growth in inequality that was coincident with rising average incomes over the past four decades. Although this is usually attributed to Skill-Biased Technological Change, our results suggest a potential role for unskilled-biased technological change.

Second, type B technological change also raises income inequality, in this case via increased competition that drives workforce reallocation and redistributes revenue across practitioners within the affected occupations. We argue that *Increasing Returns to Scale up to some Limit* are commonly present in occupations that require substantial human capital. When the limit up to which IRS operates increases for an occupation (for instance due to technological change), this generates two conflicting effects. On the one hand, the scale of operation for practitioners within the occupation increases, which benefits them. On the other hand, since this is true for all workers, they therefore face fiercer competition for their services. The latter effect is felt equally by all workers, but the benefits are greater for workers with higher human capital, who charge higher prices. The net effect is therefore to increase inequality within the occupation.

As far as we know, both mechanisms are new to the literature. In light of this, we test our model's predictions, finding patterns in the data consistent with the mechanisms we highlight.

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Appendix A. Proof of Proposition 2

Proof. k is determined by equation (22). Differentiating with respect to B on both sides, we find

$$[d(\mu^{\frac{1}{1-\hat{\rho}}} H_k^{\frac{\rho-\hat{\rho}}{1-\hat{\rho}}} h_k^{\frac{-\rho}{1-\hat{\rho}}})/dk - (A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}] \cdot dk/dB = (k-1)d(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}/dB + d[(1-k_0)(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}]/dB$$

We further know that $d(^{\frac{1}{1-\hat{\rho}}} H_k^{\frac{\rho-\hat{\rho}}{1-\hat{\rho}}} h_k^{\frac{-\rho}{1-\hat{\rho}}})/dk < 0$ because $dH_k/dk < 0$ and $\frac{\rho-\hat{\rho}}{1-\hat{\rho}} > 0$, and $dh_k/dk > 0$. Therefore, on the LHS of the equation the term in front of dk/dB is negative.

On its RHS, $d(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}/dB > 0$ and $k-1 < 0$. Therefore, if $d[(1-k_0)(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}]/dB \leq 0$, which (as $k_0 = \frac{Bc}{A+Bc}$) is equivalent to $c \geq \frac{\hat{\rho}}{1-\hat{\rho}} \cdot \frac{A}{B}$, then the RHS is negative and thus $dk/dB > 0$. □

Appendix B. Proof of Proposition 3

Proof. From (23), m_i increases with h_i^ρ. Therefore, to prove the proposition, it suffices to prove that dm_i/dB increases with h_i^ρ. By (23),

$$\frac{dm_i}{dB} = h_i^\rho / h_k^\rho \cdot [c - (A+Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB}] - c. \tag{B.1}$$

Only the first term depends on h_i. Therefore, dm_i/dB increases with h_i^ρ if and only if $c - (A+Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB} > 0 \Leftrightarrow$

$$c > (A+Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB}.$$

The identity of the marginal entertainer, k, is determined by equation (22). Taking the logarithm of both sides: $\frac{1}{1-\hat{\rho}} \log \mu + \frac{\rho-\hat{\rho}}{\rho(1-\hat{\rho})} \log H_k^\rho - \frac{\rho}{1-\hat{\rho}} \log h_k = \log(k-k_0) - \frac{\hat{\rho}}{1-\hat{\rho}} \log(A/B+c)$. Now taking the derivative with respect to B on both sides and noting that $\frac{dH_k^\rho}{dk} = -h_k^\rho$ and recalling $k_0 = \frac{Bc}{A+Bc}$: $[-\frac{\rho-\hat{\rho}}{\rho(1-\hat{\rho})} h_k^\rho / H_k^\rho - \frac{\rho}{1-\hat{\rho}} (\log h_k)'] \cdot \frac{dk}{dB} = \frac{1}{k-k_0} \cdot [\frac{dk}{dB} - \frac{Ac}{(A+Bc)^2}] + \frac{\hat{\rho}}{1-\hat{\rho}} \cdot \frac{A}{(A+Bc)B} \Rightarrow$

$$\frac{dk}{dB} = \frac{1/(k-k_0) \cdot Ac/(A+Bc)^2 - \hat{\rho}/(1-\hat{\rho}) \cdot A/[A+Bc)B]}{1/(k-k_0) + \frac{\rho}{1-\hat{\rho}}(\log h_k)' + \frac{\rho-\hat{\rho}}{\rho(1-\hat{\rho})} h_k^\rho / H_k^\rho}.$$

The numerator is smaller than $1/(k-k_0) \cdot Ac/(A+Bc)^2$, while the denominator is greater than $1/(k-k_0) + \frac{\rho}{1-\hat{\rho}}(\log h_k)'$, which is in turn greater than $1/(k-k_0) + \rho(\log h_k)'$. Therefore,

$$\frac{dk}{dB} < \frac{Ac/(A+Bc)^2}{1+\rho(\log h_k)'(k-k_0)}.$$

With this inequality, the inequality (B.2) follows from $c > (A+Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{Ac/(A+Bc)^2}{1+\rho(\log h_k)'(k-k_0)}$, which, with rearrangement and noting that $k_0 = \frac{Bc}{A+Bc}$, is equivalent to:

$$\frac{\rho \cdot h'_k/h_k}{1 + \rho \cdot h'_k/h_k \cdot (k - k_0)} < \frac{1}{1 - k_0}.$$

Note the LHS of the inequality increases with ρ and $\rho \leq 1$. The inequality, therefore, follows from

$$\frac{h'_k/h_k}{1 + h'_k/h_k \cdot (k - k_0)} < \frac{1}{1 - k_0},$$

which follows from assumption (12) as $k > k_0$. □

Appendix C. An Example in which dm_i/dB Decreases with m_i

Following the proof of Proposition 3, dm_i/dB decreases with m_i if

$$c < (A + Bc) \cdot \rho \cdot (\log h_k)' \cdot \frac{dk}{dB}. \tag{C.1}$$

To construct such an example, we therefore want $(\log h_k)'$ to be large enough. Here is one example. Let $\widehat{\rho} = 0$ and let the distribution of human capital be given by

$$h_i = \left\{ \begin{array}{c} x \text{ if } i < k - \epsilon/2 \\ x + \frac{\delta}{\epsilon}(i - k + \epsilon/2) \text{ if } k - \epsilon/2 \leq i \leq k + \epsilon/2 \\ x + \delta \text{ if } k + \epsilon/2 < i \end{array} \right\}$$

for some $\epsilon, \delta, k > 0$ and $k - \epsilon/2 > 0$ and $k + \epsilon/2 < 1$. Therefore, $h'_k = \frac{\delta}{\epsilon}$ and $h'_k/h_k \to \infty$ if $\epsilon \to 0$. For the time being, k is just a parameter. But this parameter identifies the marginal agent in equilibrium if it satisfies equation (22), which, since $\widehat{\rho} = 0$, becomes

$$\mu H_k^{\rho} h_k^{-\rho} = k - k_0. \tag{C.2}$$

With $\epsilon \to 0$, the LHS of this equation approaches $\mu \frac{(x+\delta)^{\rho}(1-k)}{(x+\delta/2)^{\rho}}$. Thus, with $\epsilon \to 0$, k approaches the root of

$$\mu \frac{(x + \delta)^{\rho}}{(x + \delta/2)^{\rho}}(1 - k) = k - k_0,$$

denoted by $\widetilde{k}$. Clearly, $\widetilde{k} < 1$.

By (B.2), with $\widehat{\rho} = 0$ and some rearrangement

$$\frac{dk}{dB} = \frac{Ac/(A + Bc)^2}{1 + \rho(\log h_k)' \cdot (k - k_0) + h_k^{\rho}/H_k^{\rho} \cdot (k - k_0)}. \tag{C.3}$$

From (C.2) it follows that $h_k^\rho/H_k^\rho \cdot (k-k_0) = \mu$. Substituting this into (C.3),

$$\frac{dk}{dB} = \frac{Ac/(A+Bc)^2}{1+\mu+\rho(\log h_k)' \cdot (k-k_0)}.$$

Then, (C.1) is equivalent to

$$\frac{1}{1-k_0} < \frac{\rho \cdot (\log h_k)'}{1+\mu+\rho(\log h_k)' \cdot (k-k_0)}, \tag{C.4}$$

where we also apply $1-k_0 = \frac{A}{A+Bc}$. Note that for the RHS of this inequality, if $\epsilon \to 0$, $(\log h_k)' \to \infty$ and $k \to \widetilde{k} < 1$, and then the RHS approaches $\frac{1}{\widetilde{k}-k_0} > \frac{1}{1-k_0}$, the LHS. Therefore, if ϵ is close enough to 0, inequality (C.4), and thus inequality (C.1), holds true, which means that dm_i/dB decreases with m_i.

Appendix D. Proof of Lemma 1

Proof. By (B.1), $\frac{dm_i}{dB} > 0$ if

$$h_i^\rho/h_k^\rho \cdot [c-(A+Bc)\cdot\rho\cdot(\log h_k)' \cdot \frac{dk}{dB}] > c. \tag{D.1}$$

With an upper bound of $\frac{dk}{dB}$ given by (B.2), this inequality follows from: $h_i^\rho/h_k^\rho \cdot [c-(A+Bc)\cdot\rho\cdot(\log h_k)' \cdot \frac{Ac/(A+Bc)^2}{1+\rho(\log h_k)'(k-k_0)}] > c \Leftrightarrow$

$$h_i^\rho/h_k^\rho \cdot [1-\frac{A}{A+Bc}\cdot\frac{\rho\cdot(\log h_k)'}{1+\rho(\log h_k)'(k-k_0)}] > 1, \tag{D.2}$$

which is equivalent to (25). $\square$

Appendix E. Proof of Lemma 2

Proof. We prove the lemma in three steps.

Step 1: If $h_1 > 1$, then

$$k-k_0 < D(\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}(1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}. \tag{E.1}$$

Proof: k is determined by equation (22), or equivalently, $k-k_0 = DH_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}}h_k^{\frac{-\rho}{1-\widehat{\rho}}}$. Note that $H_k = \{\int_k^1 h_i^\rho\}^{\frac{1}{\rho}}|_{h_i'>0} < \{\int_k^1 h_1^\rho\}^{\frac{1}{\rho}} = h_1(1-k)^{\frac{1}{\rho}}$. Therefore, $H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}}h_k^{\frac{-\rho}{1-\widehat{\rho}}} = (\frac{H_k^{\rho-\widehat{\rho}}}{h_k^\rho})^{\frac{1}{1-\widehat{\rho}}} < (\frac{h_1^{\rho-\widehat{\rho}}(1-k)^{\frac{\rho-\widehat{\rho}}{\rho}}}{h_k^\rho})^{\frac{1}{1-\widehat{\rho}}} = h_1^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}}/h_k^{\frac{\rho}{1-\widehat{\rho}}}\cdot(1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}|_{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}\le\frac{\rho}{1-\widehat{\rho}} \text{ and } h_1>1} < h_1^{\frac{\rho}{1-\widehat{\rho}}}/h_k^{\frac{\rho}{1-\widehat{\rho}}}\cdot(1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}$, which implies (E.1).

Step 2:

$$k < f(k_0, D \cdot (\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}). \tag{E.2}$$

Proof: Let $\tau := f(k_0, D \cdot (\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}})$. By the definition of $f(\cdot,\cdot)$, $\tau - k_0 = D \cdot (\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}} \cdot (1-\tau)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}$. The two sides of this inequality minus, respectively, the two sides of inequality (E.1) leads to $\tau - k > D(\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}[(1-\tau)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}} - (1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}]$. This inequality can hold true only if $\tau > k$: if $\tau \leq k$, then the LHS of the inequality is negative, while the RHS is positive – and thus cannot be strictly smaller than the LHS – because $1-\tau \geq 1-k$, which implies $(1-\tau)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}} - (1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}} \geq 0$ (as $\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})} > 0$). Q.E.D.

Step 3: We prove the Lemma by showing that $\zeta \geq h_1/h_k$ leads to a contradiction. Clearly, $f(k_0, y)$ increases with y, and therefore if $\zeta \geq h_1/h_k$, then $f(k_0, D \cdot (\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}) < (f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}})$, which together with (E.2) implies that $k < f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}})$. Since $h'(i) > 0$, then $h_k < h(\ f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}}))$. Thus we have

$$\zeta \geq \frac{h_1}{h_k} > \frac{h_1}{h(f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}}))},$$

which implies $\zeta \cdot h(f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}})) > h_1$, in contradiction to the lemma. Q.E.D. □

Appendix F. Proof of Proposition 5

Proof. k is determined by equation (22). Differentiate with respect to A on both sides, and we find

$$[d(\mu^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}})/dk - (A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}] \cdot dk/dA = (k-1)d(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}/dA + d[(1-k_0)(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}]/dA$$

We saw $d(^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}})/dk < 0$ because $dH_k/dk < 0$ and $\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}} > 0$, and $dh_k/dk > 0$. Therefore, on the LHS of the equation the term in front of dk/dA is negative.

On its RHS, $d(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}/dA < 0$ and $k-1 < 0$. Therefore, if $d[(1-k_0)(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}]/dA \geq 0$, which (as $k_0 = \frac{Bc}{A+Bc}$) is equivalent to $c \geq \frac{\widehat{\rho}}{1-\widehat{\rho}} \cdot \frac{A}{B}$, then the RHS is positive and thus $dk/dA < 0$. □

Appendix G. Internet Exposure Measure

Our measure of Internet exposure, B_{it}^{Int}, is constructed as in (27). The industry Internet sales data come from Census' E-Stats database, which provides the data at the two- and three-digit North American Industry Classification System (NAICS) level. We then concord these to the Ind1990 classification used in the CPS using a straightforward concordance provided by Census. One nuance is that some of the sales data is classified under the industry "E-Merchants" (NAICS 4541) by product, in categories such as Books and Magazines, Music and Videos, etc. We therefore match these to the relevant Ind1990 industries manually. The final step is to calculate (27).

Appendix H. Wage and Employment Regressions, Long Differences

Here we present the results of regressions identical to (28) and (29) except they are estimated as stacked long differences, covering 1985 to 1994 and 1995 to 2006. In both regressions we present a specification in which we control for computer use in the pre-Internet period.

Table H.4: Differential Wage Impact on Occupations Due to Internet Exposure

	(1) Wage Growth	(2) Wage Growth	(3) Wage Growth	(4) Wage Growth
Internet Exposure	0.0411	0.0378	0.0379	0.0348
	(0.0264)	(0.0268)	(0.0273)	(0.0264)
Base Wage		-0.00325***	-0.00325***	-0.00298***
		(0.00103)	(0.00102)	(0.00104)
Base Wage x Internet Exposure		0.208***	0.208***	0.205***
		(0.0440)	(0.0441)	(0.0437)
Occ Trend			0.000	0.000
			(0.000)	(0.000)
Computer Exp, 85-94				0.0125
				(0.009)
Observations	9537	9537	9537	9227
Occ FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Standard errors in parentheses are clustered at the occupation level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table H.5: Differential Employment Impact on Occupations Due to Internet Exposure

	(1) Emp Growth	(2) Emp Growth	(3) Emp Growth	(4) Emp Growth
Internet Exposure	-0.0417	-0.0417	-0.0429	-0.0592
	(0.052)	(0.052)	(0.052)	(0.051)
Occ Trend			-0.000	0.000
			(0.000)	(0.000)
Computer Exp, 85-94				0.003
				(0.003)
Observations	645	645	645	593
Year FE	Yes	Yes	Yes	Yes

Standard errors in parentheses are clustered at the occupation level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$