Search Engines vs Steam Engines: Technological Change, 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. To do this, we develop a model in which agents choose to supply either unskilled labor or human capital. Type A technological change allows unskilled labor to produce more output per unit of time, thereby increasing the unskilled wage, but has no direct effect on the return to human capital. It does, however, increase the return to human capital via a general equilibrium effect and this increase is even larger than the rise in the unskilled wage, thereby increasing overall income inequality. Type B technological change expands the scale of operation for workers in certain human-capital-intensive occupations. Technological progress of this type is modeled as an increase in the extent to which an occupation's production technology displays Increasing Returns to Scale. It enlarges the capacity of each worker while simultaneously increasing competition between workers. The negative effect of competition dominates for workers whose human capital lies at the lower end of the distribution. The least endowed workers are squeezed out of the occupation and become labor providers, while the next least endowed workers remain in the occupation but earn less. Type B technological progress raises income inequality within the occupations in which it occurs. We compare the theoretical results with U.S. and Chinese data and find support for the predictions.

JEL: J24, J31, O30, D33

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

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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 enables a given amount of output to be used or consumed to a larger extent 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, or even new occupations such as "unboxing" in which presenters open a box of toys before the camera in a manner that is appealing to children. While the Internet does not reduce the time or effort required of a presenter to do her work, it does enable her work to reach an audience far beyond what face-to-face interaction would allow, potentially raising her income substantially. This paper considers both types of technological change within a unified model and finds that they have very different implications for the income distribution as well as individuals' career choices.

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 a great loss of effect. 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 to scale (CRS). Our innovation consists in the observation that the CRS often operate up to some limit. For example, it is costly

[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.

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, 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 all 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.

Another observation we make is 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 a fraction of 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 with one another in a market that is much more competitive, and they 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 her time to supply human capital rather than labor, a professional hires labor to produce her variety of services at constant returns to scale 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, potential scale of operation for all professionals, but does not

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

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 sell more, which benefits them. On the other hand, since the 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 capacity delivers greater benefits to those who have greater 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: the change in their income induced by an increase in B is an increasing function of the current income, that is, the more they are earning now, the less they lose or the more they gain. And (b) there exists a critical level of human capital such that professionals with human capital below this point lose from the increase in B. Furthermore, (c) there is another, lower threshold of human capital such that professionals below this point are squeezed out of the profession and must subsist on the provision of 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 professionals with greater human capital acquire a larger fraction of aggregate income by providing better quality services, a larger fraction of the increase in aggregate income accrues to them. As a result, an increase in A (d) increases income inequality, while (e) also increasing the income level of all workers. With respect to occupational choice, we show that (f) 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 and therefore allows more agents to earn a living by providing human capital, for instance becoming managers, painters, or writers. Moreover, with the economy becoming richer the demand for these services rises, thereby leading the marginal laborers to shift into the provision of services.

We extend our model to consider the impact that an increase in the IRS limit in one occupation

[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.

(for example, the impact of the radio on musicians) has on another occupation for which the limit of IRS is unchanged (for example, dancers), which we refer to respectively as the "affected" and "unaffected" occupations. We show that (g) 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 the latter's services or products relatively more expensive.

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 broad-based income growth has, somewhat paradoxically, often led to rising inequality. Specifically, the above results (d) and (e) together provide an explanation for the observed relationship between aggregate economic growth and rising inequality in countries such as China, which is the focus of our empirical exercise. The so-called Kuznets curve depicts this basic relationship, and the most prominent explanation for the relationship focuses on 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 observed 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 predictions (a) and (b) concerning the occupations for which the limit of IRS has been increased with the Internet. To identify these affected occupations, 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; and consistent with prediction (b), we find that that the expansion of the Internet is associated with wage losses for lower-end workers. We also test the model's predictions with respect to patterns of employment, given by results (c) and (f) 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. Section 3 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 argument is the model of Skill-Biased Technical Change (SBTC), which has recently been updated by Acemoglu and Autor (2011) to endogenize the matching of skills to production tasks.[4] Relative to SBTC and its extensions, our paper considers additional facets of technological progress and therefore ultimately presents a complementary approach.

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 discover 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 the technological progress complements the tasks or substitutes 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 the 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 conventional approach, 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 higher earners reap larger gains from an increase in aggregate

[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.

income, which is the primary effect of type A technological change. This general equilibrium 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 a strand of literature that seeks to explain certain features of top earnings, such as the earnings of "superstars" or CEOs; see Rosen (1981), Rosen (1983), Gabaix and Landier (2006), and Egger and Kreickemeier (2012), and 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. At the same time, it offers only an informal discussion regarding the potential impacts of an increase in the scale of operation, namely a type B technological change.[8] In contrast, we model type B change with a new approach and formally consider its implications for the income distribution and career choice.[9] Second, our model is ultimately not about superstars. We study the career choice margin, between providing labor and becoming a low-end professional (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 within 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. However, both papers feature monopolistic competition with CES preferences, IRS, and agent heterogeneity,

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[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 is all 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 captures the effect that type B progress increases competition between workers, which consequently generates losses for the lowest earners among 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).

and 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 both reflect 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 (i.e. muscles) or on their human capital (i.e. brains).[12] In the latter case, they provide a stream of services which, to fix ideas, we assume throughout to be entertainment services (which we previously referred to more generally as professional services). The quality of the services provided by an agent depends on the size of her 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.

[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 muscle and brain. But clearly some occupations demand more of human capital relative to labor, while others demand relatively more of labor. For simplicity, we abstract from this continuum of human capital-to-labor ratios, modeling it as a binary choice.

The production of the subsistence good displays constant returns to scale. If L agents are employed to produce the subsistence good, then its aggregate output is

$$Y = AL.$$

The production of entertainment services requires two factors, human capital and labor. In this paper, we let human capital affect only the quality of the output and abstract from the effect of human capital on the quantity, for simplicity of exposition. If an agent chooses to live on his human capital endowment and provide entertainment services, then his human capital affects the quality of the entertainment services in two ways. First of all, his human capital is unique in some dimensions, and therefore so are the services that he provides (for instance, consider the difference between Jay-Z and Madonna). As a result, each entertainer provides a unique variety of entertainment services, indexed by her identity $i \in [0, 1]$ and different agents' entertainment services compete under monopolistic competition. Secondly, the entertainment service provided with a higher level of human capital is of a better quality, in the sense that it gives consumers a higher value, as will be shown when we come to the utility of the agents. Regarding the quantity of output, since we abstract from the effect of human capital on it, it follows that all agents have the same production function. Specifically, if an agent hires L units of labor, the output of her 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, if an agent decides to use his time in order to supply human capital, thereby providing a variety of entertainment services, rather than to supply labor, he can subsequently hire labor to produce output at constant returns to scale up to the limit B. Thus, the production of entertainment services displays Increasing Returns to Scale up to some limit (IRSL).

An alternative way to see this is to consider the cost function. Let F denote the opportunity cost of the agent's time[13] and w the wage of labor. Then the cost function associated with producing her variety of entertainment services is

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

[13] Since the alternative use of his time is to supply labor, we have that $F = w$.

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 her utility is

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

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. Note that the marginal value of agent i's services is h_i, the same as the amount of her human capital. That is, the entertainment services provided with high human capital deliver a greater value to consumers, as noted above.

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 are, respectively:[14]

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

where P is the general price of entertainment services and

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

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

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. Note that $D'_h > 0$. This is due to the fact that consumers derive greater value from a variety of service that is provided with relatively higher human capital, and hence have a larger demand for it, conditional on price.

If an agent with human capital h chooses to supply labor and produce the subsistence good, he gets A. Hence in equilibrium the wage of labor employed in the production of entertainment services is also A, that is, $w = A$. Therefore, by (2), the marginal cost of producing entertainment services up to scale B is $w\frac{c}{A} = c$, which is independent of A. If the agent chooses to live on his human capital and produce his variety of services, the demand for his 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), $m'(h) = D'_h > 0$. 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

$$m(h_k) = A.^{15} \tag{9}$$

[15] 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

For $i < k$, agent i earns wage $w = A$, and for $i \geq k$ agent i earns $m(h_i)$, the rents associated with her human capital. Hence the set of available entertainment services is $E = [k, 1]$. It follows that the price index for entertainment services, from (4), is given by

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

and the aggregate income is

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

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 given by (11).[16]

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 $[\log h(x)]' < 1/(1 - x)$,[17] which says that $\log h(x)$ does not grow too fast.

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 focus on the case in which the capacity constraint, $D(p; h) \leq B$, is binding for any agents who choose to be entertainers, such that their profit is $(p - c)B$. This effectively requires B to be sufficiently small; an exact condition for this is provided in Subsection??. In that subsection, we also show that the insights derived from this case can then be applied straightforwardly to the case in which the capacity constraint is not binding for some portion of the entertainers. Of course, if it is not binding for any agents then an increase in B will

of it 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.

[16] 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.

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

have no effect.

Applying the binding capacity constraint, $D(p, h_i) = B$, the price of the variety of entertainment services provided by agent i is:

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

Thus, an agent with higher human capital charges a higher price for her services because they deliver a higher value to consumers. In fact, the price is proportional to the marginal value raised to power $\rho < 1$ – that is, h_i^{ρ} – because a variety of entertainment services is not a perfect substitute for another, in general. In the special case in which it is – that is $\rho = 1$ – the price of a variety is then directly proportional to its marginal value.

With the price of each variety given by (13), the price index, from (10), is

$$P = \Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} H_k^{\rho-1}, \tag{14}$$

where

$$H_k := \Big\{\int_k^1 h_i^{\rho}\Big\}^{\frac{1}{\rho}}. \tag{15}$$

This equation for the general price of entertainment services leads to two results. One, it implies that $M/(BH_k) = P^{\frac{1}{1-\rho}}/f(P,\mu)$. With $f(P,\mu) = \frac{P^{\frac{\rho-\widehat{\rho}}{(1-\rho)(1-\widehat{\rho})}}}{\mu^{\frac{1}{1-\widehat{\rho}}}+P^{\frac{\widehat{\rho}}{\widehat{\rho}-1}}}$, it follows that

$$P + (\mu P)^{\frac{1}{1-\widehat{\rho}}} = \frac{M}{BH_k}. \tag{16}$$

The other result, from (14), is $\Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} = PH_k^{1-\rho}$. Substituting this into (13), we have $p_i = PH_k^{1-\rho}h_i^{\rho}$. Since the profit of an entertainer i is $m(h_i) = (p_i - c)B$, then

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

The first term on the right hand side reflects revenue, which we denote by $R(h_i)$, while the second term reflects labor costs. The revenue is proportional to capacity, the general price of entertainment services, and the entertainer's human capital raised to the power ρ. The first two factors are common to all the entertainers. Hence, an entertainer's revenue is proportional to his human capital raised to the power ρ – i.e., the price she charges. This suggests that the fraction of aggregate spending on entertainment services that flows to entertainer i is $h_i^{\rho}/\int_k^1 h_j^{\rho} = h_i^{\rho}/H_k^{\rho}$ which, since $R(h_i) = BPH_k \times h_i^{\rho}/H_k^{\rho}$, suggests that the aggregate spending on entertainment services is BPH_k. This is indeed the case. It follows from equation (16) that $BPH_k = \Big(\frac{1}{1+\mu^{\frac{1}{1-\widehat{\rho}}}P^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}}\Big)M$. Moreover, from (3), the fraction of each agent's income, and hence aggregate income, spent on the subsistence good is $\frac{1}{1+\mu^{1/(\widehat{\rho}-1)}P^{\widehat{\rho}/(\widehat{\rho}-1)}}$. Thus, the fraction spent on entertainment services is $1-\frac{1}{1+\mu^{1/(\widehat{\rho}-1)}P^{\widehat{\rho}/(\widehat{\rho}-1)}} = \frac{1}{1+\mu^{\frac{1}{1-\widehat{\rho}}}P^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}}$. Hence, BPH_k is indeed the aggregate spending on entertainment services. Note that for the Cobb-Douglas case, where $\widehat{\rho}=0$, this fraction is $1/(1+\mu)$, and thus is independent of the price of entertainment, P. As a result, entertainer i obtains a fraction h_i^{ρ}/H_k^{ρ} of the aggregate spending on entertainment services. It also follows from (16) that $BH_k(\mu P)^{\frac{1}{1-\widehat{\rho}}}$ is the aggregate spending on the subsistence good.

Having found the profit of each entertainer, we now move on to determining the career choice threshold, k, in two steps. First, 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

$$PH_k^{1-\rho}h_k^{\rho} = c + \frac{A}{B}. \tag{18}$$

Note that the term on the right hand side is the price charged by the marginal entertainer, i.e. agent k. As the marginal entertainer, her profit is A and hence the price she charges satisfies $p_k \times B - Bc = A$. Hence

$$p_k = A/B + c.$$

Second, with the profit of individual entertainers given by (17), aggregate income, from (11), is:

$$M = kA - (1-k)cB + BPH_k. \tag{19}$$

As noted above, the last term, BPH_k, is the aggregate spending on entertainment services. The first two terms represent the aggregate supply of the subsistence good (which, in equilibrium, equals the aggregate spending on the good). Specifically, agents $j \in [0,k]$ are supplying labor to the economy, of whom (from (1)) $\frac{c}{A}B\times(1-k)$ agents are working for entertainers. Thus, $k-\frac{c}{A}B\times(1-k)$ are engaged in production of the subsistence good, yielding an output of $[k-\frac{c}{A}B\times(1-k)]\times A = kA-(1-k)cB$. Note that this aggregate supply of the subsistence good can be re-written as $(A+Bc)(k-k_0)$, where $k_0 = \frac{Bc}{A+Bc}$ is the threshold for the number of agents at which the aggregate supply of the subsistence good is zero. To understand this equation we first observe that $A+Bc$ is the marginal product of one more agent choosing to supply labor rather human capital in producing the subsistence good, taking into account the quantity of labor that is saved, $\frac{c}{A}B$, due to the agent's abstaining from production of the entertainment services. Since $A+Bc$ is the marginal product of the choice to supply labor, it is also the revenue of the marginal entertainer, k, as we saw above. With the supply function being $(A+Bc)(k-k_0)$, k_0 can be regarded as the fixed cost associated with the decision to supply human capital rather than labor.

Canceling out M using (16) and (19), we have

$$BH_k(\mu P)^{\frac{1}{1-\widehat{\rho}}} = (A + Bc)(k - k_0).$$

As we have seen above, the left hand side of this equation is aggregate spending, and the right hand side is the aggregate supply of the subsistence good. As a result, this equation reflects market clearing for the subsistence good. Substituting for P with the solution from (18) and re-arranging, we arrive at a single equation that pins down k in equilibrium:

$$\mu^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}} \times (A/B + c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}} = k - k_0 \tag{20}$$

Again, as noted above, the term on the right hand side of this equation is the aggregate supply of the subsistence good, measured in units of the revenue of the marginal entertainer (i.e., $A + Bc$), if his identity is k. The term on the left hand side of this equation, as we have explained above, is the aggregate spending for the subsistence good *conditional on the marginal entertainer being agent* k, also measured in revenue units. This can be clearly seen for the Cobb-Douglas case, where $\widehat{\rho} = 0$. In this case, this term simplifies as $\mu H_k^{\rho}/h_k^{\rho}$. Measured in units of the agent's revenue, the spending on his service (the agent's revenue) is 1. Since this spending is h_k^{ρ}/H_k^{ρ} of the aggregate spending on entertainment services, the spending on his service is therefore H_k^{ρ}/h_k^{ρ}, and then μ times this term gives the aggregate spending on the subsistence good in the Cobb-Douglas case, where the ratio of the spending on the subsistence good to that on entertainment services is always μ, independent of the price index, P.[18] For the non-Cobb-Douglas case, this ratio depends on the price and hence we have the additional term $(A/B + c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}} = (p_k)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$. In particular, if entertainment services are cheaper, reflected in a smaller p_k, then spending on the subsistence good is reduced, as it becomes relatively more expensive (in the case of $\widehat{\rho} > 0$) such that the price effect dominates the income effect.

The aggregate supply of the subsistence good – the right hand side term – increases with k due to the fact that the larger is k, the more agents there are that will supply labor – i.e., fewer agents will work for entertainers and will instead produce the subsistence good. At the same time, aggregate spending – on the left hand side – decreases with k, the identity of the marginal entertainer, and spending goes to zero as k goes to 1.[19] Intuitively, this is because an agent with relatively little human capital chooses to become an entertainer only if the economy is rich enough such that a

[18] In the Cobb-Douglas case, each agent spends a fraction of $\frac{\mu}{1+\mu}$ of his income on the subsistence good and that of $\frac{1}{1+\mu}$ on entertainment services. Hence the aggregate spend on the former good is μ times that on the latter good.

[19] 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, $H_1 = 0$. Hence the term on the left hand side equals 0 at $k = 1$.

large enough aggregate income is spent on entertainment services. Put differently, if the marginal entertainer has a relatively high human capital level – i.e. k is big – then the economy must be poorer, which means the aggregate spending on the subsistence good is smaller too. In the extreme case, if the economy can support only the agent with the greatest human capital as an entertainer – i.e. $k = 1$ – then it must be extremely poor in that aggregate income approaches zero and each agent can only spare a tiny amount of income to spend on entertainment services.

Equation (20) can be re-arranged into

$$\mu^{\frac{1}{1-\hat{\rho}}} H_k^{\frac{\rho-\hat{\rho}}{1-\hat{\rho}}} h_k^{\frac{-\rho}{1-\hat{\rho}}} = (A/B + c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}} (k - k_0), \tag{21}$$

As argued above, the left hand side of (21) decreases from a positive number to 0 with k ascending from k_0 to 1, and with this movement of k the right hand side of (21) linearly increases from 0 to some positive number. Both sides are depicted in Figure 1 below.

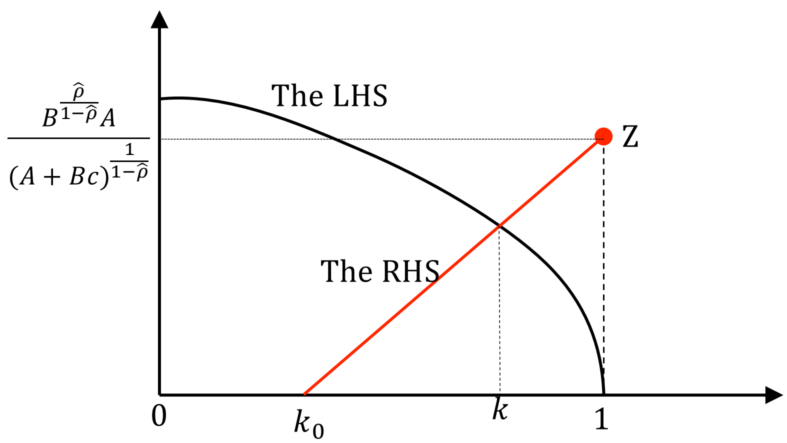


Figure 1: The Existence and Uniqueness of Equilibrium

This argument clearly shows that:

Proposition 1. *A unique equilibrium exists, in which $k \in (k_0, 1)$ and is given by (21).*

The economic intuition for the existence and uniqueness of an equilibrium can be understood in light of the CES preferences 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, in which case their income, m_i, is related to their human capital according to (17). Simplify this equation with $PH_k^{1-\rho} = (c + A/B)h_k^{-\rho}$ (from equation (18)) we find that the equilibrium income distribution is:

$$m_i = \left\{ \begin{array}{l} A \text{ if } i < k \\ (Bc + A)\frac{h_i^\rho}{h_k^\rho} - Bc \text{ if } i \geq k \end{array} \right\} \tag{22}$$

This income distribution is illustrated in Figure 2.[20]

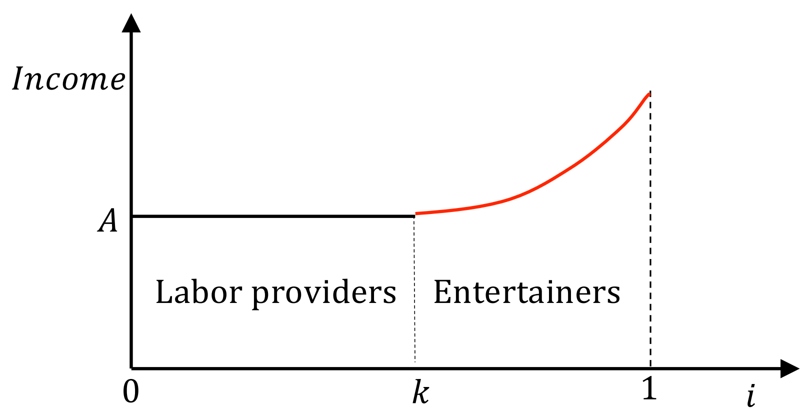


Figure 2: The Equilibrium Income Distribution

4.1. The Effects of Type-B Technological Progress

Here we consider the comparative statics with respect to B.[21] We consider first how an increase in B affects the occupational choice of the agents, captured by k, and then its effect on the income distribution. The equilibrium k is determined by equation (20), from which we can see that an increase in B generates two effects that impact k. First, from the right hand side of (20), $k_0 = Bc/(A + Bc)$ increases with B and, hence, for a given k the value of the term, which represents the aggregate supply of the subsistence good, decreases with B. Intuitively, a larger B means that more labor is required as input into the production of entertainment services. Conversely, given the

[20]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.

[21]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.

total supply of labor (i.e., k), the fewer workers that are employed to produce the subsistence good the less that is produced. As result, given some amount of aggregate spending on – i.e. demand for – the subsistence good, a rise in B implies that more agents will supply labor as input into entertainment services in order to meet the increased demand for them. That is, the supply side alone drives k up. The second effect, from the left hand side of (20) (which represents the aggregate demand for the subsistence good), is that the price adjustment term, $(A/B+c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$, decreases with B. Intuitively, when the quantity of each variety increases, entertainment services in general become relatively cheaper, which reduces the demand for the subsistence good when $\widehat{\rho}>0$. This demand-side effect alone reduces demand for the subsistence good and hence decreases the number of agents that provide labor; that is, it drives k down.

These two effects therefore drive k in opposite directions. The trade-off between them determines its ultimate direction – up or down. As we saw, the demand side effect depends on the value of $\widehat{\rho}$ and vanishes at $\widehat{\rho}=0$ where the price effect is completely offset by the income effect. By continuity, we expect this effect to be weak and dominated by the positive effect on the supply side – hence k to go up – if $\widehat{\rho}$ is close enough to zero. To find a sufficient condition for this tradeoff, we turn to equation (21), the two sides of which are pictured in Figure 3. We note that the left hand side 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, driving k to rise to k'. 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 (to the position of k'), as is illustrated in the left panel of Figure 3. If Z moves down then k shifts further to the right (to the position of k''), as is illustrated in the right panel of the Figure.

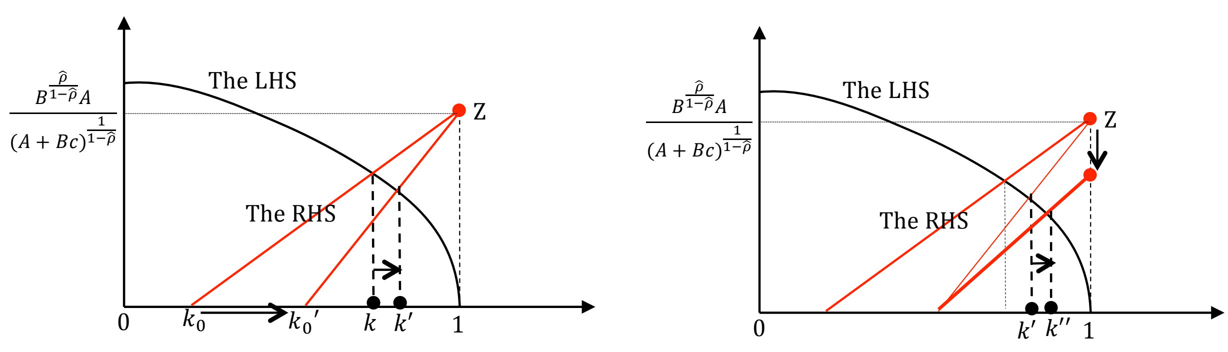


Figure 3: The effect of an increase in B on k. The left panel: an increase in B moves k_0 to k', which increases k to k'. The right panel: if point Z moves down, then k is shifts further to k''

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

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

which is equivalent to

$$c \geq \frac{\widehat{\rho}}{1-\widehat{\rho}} \cdot \frac{A}{B} \tag{23}$$

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 an increase 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.1. □

According to the proposition, if $\widehat{\rho}$ is small – so the price effect is mostly cancelled by the income effect – then the marginal entertainer is competed out of the entertainment occupation to become labor providers as a result of an increase in B. The intuition for the Cobb-Douglas case, where $\widehat{\rho} = 0$, is as follows. 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 live on their human capital. In other words, he is squeezed out into labor provision.

Having examined the effect of an increase in B on career choice, we move on to considering its effects on the income distribution. Two effects are presented below. The first is a direct implication of Proposition 2: fiercer competition due to an increase in B generates losses for lower-end entertainers. 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 relegate the proof to Appendix A.2. □

The second effect of a rise in B for the income distribution is that it increases income equality within the entertainment occupation, as the following proposition shows.

Proposition 4. *Under condition (12), for $i > k$, dm_i/dB increases with i and hence is positively correlated with m_i.*

Proof. We relegate the proof to Appendix A.3. □

That is, the larger the current income of an entertainer, the more the entertainer gains (or the less she loses) from an increase in the limit of IRS, which leads to growth in income inequality within the entertainment occupation. The intuition for the proposition is as follows. An increases in B generates three effects on the revenue of entertainers, aside from increasing their costs, Bc. First, a positive effect: a rise in B enlarges entertainers' capacity and thereby increases their revenues. Second, a negative effect: since all entertainers are equally exposed to the increased capacity, the competition between them becomes fiercer, resulting in a lower general price of entertainment services, which reduces revenues (all else equal). And third, an increase in B may affect aggregate income, thereby affecting entertainers' revenues. The sign of this effect is unclear, *a priori*. Setting the third effect aside – more discussion regarding this effect is presented below – all entertainers face the fiercer competition to the same degree, since they face the same lower general prices of entertainment services, but an entertainer who has relatively more human capital – and thus earns relatively more – gains relatively more from the enlargement of the capacity because he provides a relatively better quality of service and is therefore able to charge a higher price for his variety.[22] As a result, entertainers with initially higher earnings gain more or lose less from an increases in B. Indeed, Proposition 3 shows that if an entertainer's human capital is low enough, then his gains from the enlargement of capacity is dominated by the losses due to fiercer competition and raised labor costs.

With an increase in the limit of IRS for any particular occupation the third effect above, which operate via the impact on aggregate income, should not be salient in reality because economies in fact consist of hundreds of occupations such that any change in one occupation is unlikely to have a large effect on aggregate income. However, in the model economy, there is only one human capital intensive occupation – namely entertainment – and hence an increase in the limit of IRS for this occupation does in fact generate a salient effect on the aggregate economy. Indeed, if the condition assumed in (12) does not hold, this effect can be so negative that Proposition 4 is invalidated and dm_i/dB decreases with m_i. In Appendix B, we construct an example of this case. Intuitively, this is because if, due to a decrease in aggregate income, the aggregate spending on entertainment services is reduced by ΔM then, other things fixed, the revenue of entertainer i is reduced by $h_i^\rho/H_k^\rho \times \Delta M$ due to the fact that she acquires a fraction h_i^ρ/H_k^ρ of that spending. Hence, if aggregate income falls,

[22] The price he charges, by (13), is in proportion to h_i^ρ.

entertainers who currently earn relatively more suffer a relatively greater loss – namely, dm_i/dB is negatively correlated with m_i.

As noted previously, an entertainer's gain from the enlargement of capacity is in proportional to her human capital endowment raised to power ρ (as is the price she charges). If an entertainer's human capital endowment is high enough the increment in revenue will outweigh the losses due to fiercer competition and raised labor costs, and the entertainer acquires a net gain due to an increase in B. To state this formally, let

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

By assumption (12), $\Omega(\rho) \cdot A/(A + Bc) < 1$.[23] 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*

$$\frac{h_i}{h_k} > \left(\frac{1}{1 - \Omega(\rho) \cdot A/(A + Bc)} \right)^{\frac{1}{\rho}}. \tag{24}$$

Proof. We relegate the proof to Appendix A.4. □

Condition (24), 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 A.5. □

[23] By the envelope theorem, $\Omega(\rho)$ 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 $\frac{A + Bc}{A}$.

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 $h_1 \geq \xi \cdot h(f(k_0, D \cdot \xi^{\frac{\rho}{1-\rho}}))$, then $dm_1/dB > 0$.*

When this proposition holds, the top entertainers gain on net from an increase in the limit of IRS. This result, 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. The consequent pattern of employment growth is illustrated in Figure 5.

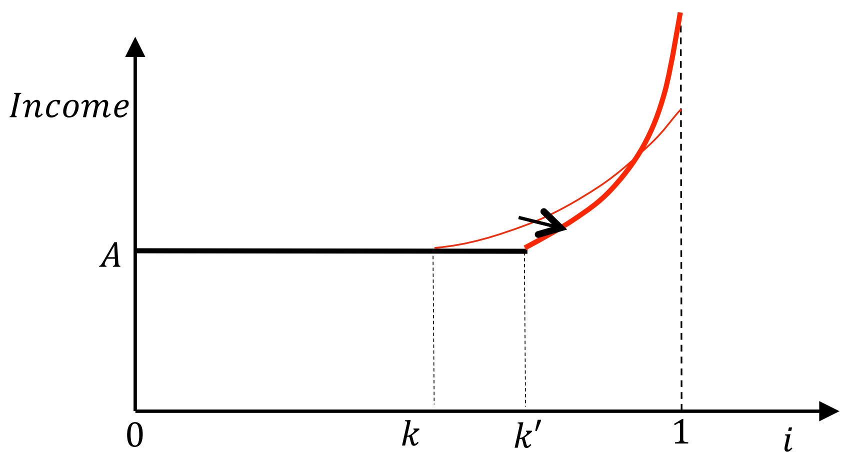


Figure 4: An increase in B squeezes the lower-end entertainers out, and raises income inequality within the entertainment occupation.

4.2. The Effects of Type-A Technological Progress

We now consider the comparative statics with respect to A, the productivity of labor. As in the case of type B change, we first explore how an increase in A affects agents' occupational choices and, second, we explore its effect on the income distribution. To begin, observe that a rise in A directly increases the income of labor, but has no direct impact on the income of entertainers. That is because an increase in labor productivity increases the productivity of entertainment services, in the sense that fewer workers are needed to produce the same amount of entertainment, but on the other hand

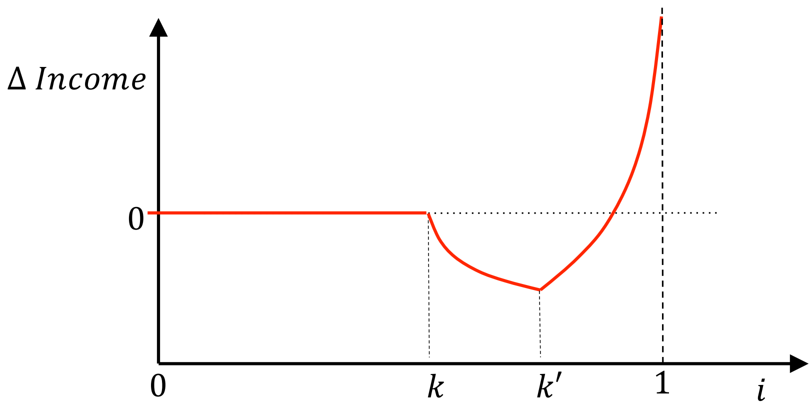
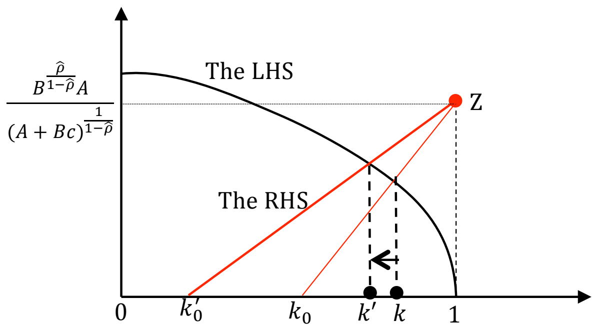


Figure 5: Income growth due to type B technological change.

it increases the wage of labor and, on net, the marginal (labor) cost of producing entertainment services, $w \times c/A$, stays constant at c from (2). In this sense we say that an increase in A is biased toward (unskilled) labor, although it also formally increases labor productivity in the entertainment occupation. It therefore seems at first glance as if an increase in A would induce more agents to provide labor, fewer to become entertainers, and would reduce income inequality. However, we show below that these direct effects are in fact fully offset by a general equilibrium effect. Specifically, an increase in A raises aggregate income, which will raise the spending on entertainment services and consequently enrich entertainers relative to labor providers. This general equilibrium effect, we will show, dominates the direct effect for the impact on both career choice and the income distribution.

To consider the impact on career choice, we return to equation (20), which determines equilibrium k via market clearing of the subsistence good. The supply side (the right hand side of the equation) increases with A since $k_0 = Bc/(A + Bc)$ decreases with it. Intuitively, given some quantity of labor k, output of the subsistence good rises with labor productivity. For fixed demand, this effect on the supply side induces fewer agents to produce the subsistence good – that is it induces k to go down. On the demand side (the left hand side of equation 20), the price adjustment factor, $(A/B + c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$, also increases with A as long as if $\widehat{\rho} > 0$. Intuitively, a larger A, by inducing a greater supply of the subsistence good, makes the entertainment services relatively more expensive and increases the demand for the subsistence good in the non-Cobb-Douglas case. This effect on the demand side induces k to go up. The effect, however, vanishes if $\widehat{\rho} = 0$ and as a consequence we expect that it will be dominated by the negative effect on the supply side when $\widehat{\rho}$ is small. To find a sufficient condition for this dominance, we again go to equation (21), the two sides of which are depicted in Figure 6. The LHS, represented by the curve, is independent of A. Thus, the curve in Figure 6 does not shift with an increase in A. As for the RHS, an increase in A shifts the straight line in Figure 6 in two ways. First, $k_0 = Bc/(A + Bc)$ falls with an increase in A and the position of k_0 shifts leftward to the position of k_0'. 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, to k', as is illustrated by the left panel of the Figure. If Z moves upward, then k falls further to k'', as is illustrated by the right panel of the Figure.



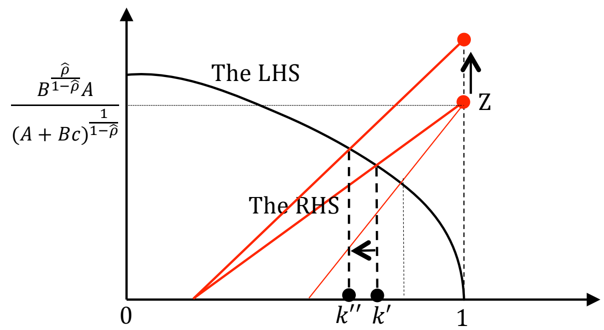


Figure 6: The effect of an increase in A on k. The left panel: an increase in A moves k_0 to the left, which decreases k to k'. The right panel: if Z moves upward, then k falls further to k''

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

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

which is equivalent to (23). Therefore,

Proposition 6. *If $c \geq \frac{\hat{\rho}}{1-\hat{\rho}} \cdot A/B$ – i.e., (23) holds – then $dk/dA < 0$.*

Proof. We relegate the proof to Appendix A.6. □

Thus, with a rise in labor productivity more agents choose to provide entertainment services, and the number of varieties therefore increases. This means that the general equilibrium effect dominates the direct effect in the impact of an increase in A on career choice. Again, to directly see how the marginal entertainer changes, we consider the Cobb-Douglas case (where $\hat{\rho} = 0$) for intuition. If A increases by one percent, then labor's income increases by the same amount. If total entertainer 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 entertainer's revenue, in particular the marginal entertainer's, increases by one percent, while their (labor) costs stay the same, equal to Bc. As a result, the marginal entertainer's income increases by more than one percent, i.e., more than the increment of the agents immediately below him. These agents, therefore, are drawn to become entertainers. Thus, the identity of the marginal entertainer, k, goes down.

Having examined the effect of an increase in A on career choice, we move on to considering its effects on the income distribution. We noted that an increase in A directly benefits unskilled labor, but has no direct impact on the income of entertainers. However, we have also noted that entertainers will gain indirectly from the general equilibrium effect. In fact, they gain more than the labor providers by the following proposition, and the more they currently earn, the more they gain. Hence, the general equilibrium effect dominates the direct effect here as well. To understand this proposition, note that if agent j provides labor, then his income is $m_j = A$ and hence $dm_j/dA = 1$.

Proposition 7. *If $i \geq k$, namely if agent i is an entertainer, then $\frac{dm_i}{dA} > 1$. Moreover, $\frac{dm_i}{dA}$ increases with i and hence is positively correlated with m_i.*

Proof. We relegate the proof to Appendix A.7. □

Of the two results presented in the proposition, the second one can be intuitively explained as follows. The major effect of an increase in labor productivity is to raise aggregate income. With the economy made richer, the agents spend more on entertainment services. As an entertainer, i acquires a fraction h_i^ρ / H_k^ρ of the aggregate spending on entertainment services. Hence, the more an entertainer currently earns, i.e., the higher is her human capital, the greater is the growth in her income from an increase in A.

To understand the first result – namely, that all the entertainers gain more than all labor providers due to an increase in A – we only need to understand why the marginal entertainer gains more than any of the labor providers. This is a direct implication of the change in career choice, as stated in Proposition 6. The marginal entertainer earns $m_k = A$. If her earnings rise with A less than one to one, she would strictly prefer to provide labor with the increase in A and then k would increase, which is not the case by Proposition 6. Hence, the marginal entertainer gains more than any labor provider due to an increase in A.

By Proposition 7, for the whole population, the more an agent currently earns, the more he gains from an increase in A. Therefore, *a rise in the productivity of unskilled labor increases overall income inequality.* The effect on the income distribution is illustrated in Figure 7.

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:

$$\Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} h_k^\rho \geq \frac{c}{\rho}. \tag{25}$$

Hence if this condition holds, then the previous analysis holds.

If the condition does not hold, then 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 true 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. That is because the marginal entertainer, now with a non-binding capacity constraint even with the present value of B, gains nothing from an increase in it. Therefore, the marginal entertainer now obtains no positive effect due to the loosening of the capacity constraint. As a result, there is now an additional reason that he is adversely affected by the increase in B 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 if the top entertainer's human capital is high enough, then she 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 because they are able to charge higher prices as they provide higher valued services. 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 seek work employing their human capital – though the exact condition may change. For the Cobb-Douglas case where $\widehat{\rho} = 0$ this is true and hence it is also true if $\widehat{\rho}$ is close enough to 0. It holds true for the

Cobb-Douglas case due to the same intuition. 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 her labor cost stays the same. As a result, her income rises by more than one percent, thus making the marginal entertainer strictly prefer the entertainment business and thus inducing entry into entertainment. This argument suggests that a one percent increase in A moves k leftward.

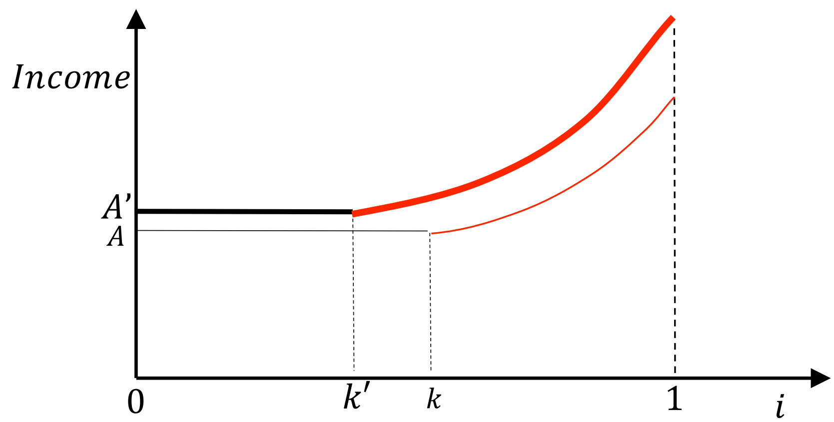


Figure 7: An increase in A raises all agents' incomes while also increasing income inequality.

Proposition 7 still holds, namely relatively more talented (and thus richer) entertainers gain relatively 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 a bigger fraction of this increase accrues to an entertainer with higher human capital because he acquires a bigger fraction of the aggregate spending on entertainment services.

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 – such as doctors or watch repairers – 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, 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 to produce another type of service (the unaffected service). Thus, each agent j makes an occupational choice between providing labor and providing services. The production of services is similarly subject to IRS up to limit $\widetilde{B}$:

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

(This $\widetilde{B}$, for example, denotes the maximum number of patients that a doctor can see.) 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 unaffected 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 incomes in the unaffected occupation? 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 impacts the unaffected occupation in the following two ways.

1. The 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 unaffected services: a negative substitution effect and a positive income effect. For the CES case that we are considering, if $\widehat{\rho}$ is positive, then the negative substitution effect dominates the positive income effect and the workers in the unaffected occupation are adversely affected. If $\widehat{\rho}$ equals zero (the Cobb-Douglas case), then these two effects exactly offset each other and these workers are not affected. Finally, the net effect will be positive if the unaffected services and affected ones are complements ($\widehat{\rho} < 0$).[24]

2. The aggregate income effect: aggregate income may increase or decrease with the increase in B, which may then impact unaffected workers positively or negatively.

In addition, we can derive in parallel that a worker with higher human capital in the unaffected occupation acquires a greater share of aggregate spending on unaffected services.

Finally, note that if B is unchanged then there is no "affected occupation". Furthermore, in this case an increase in A affects both occupations in the same way as explained above.

[24]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).

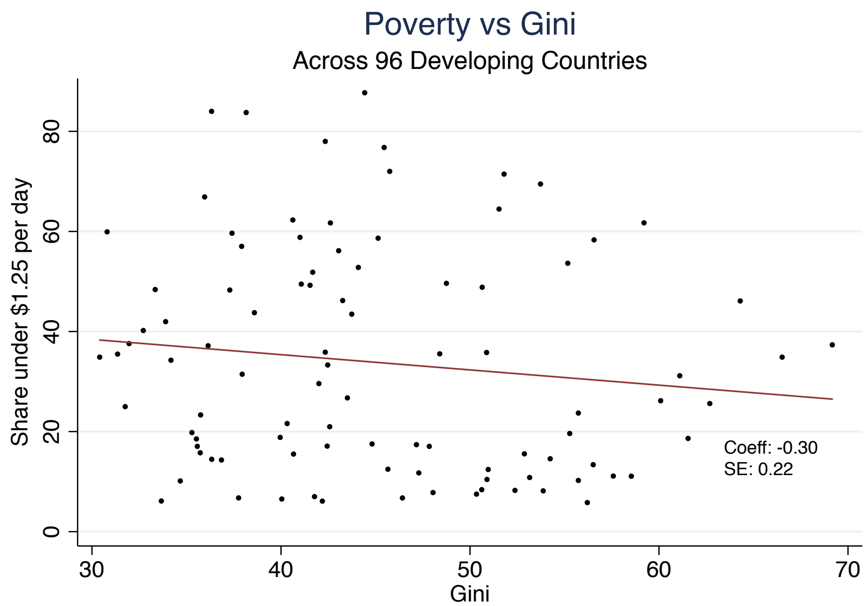


Figure 8: Poverty and Inequality. Source: United Nations

5. Empirical Patterns

In this section we bring the theoretical results derived in 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

A in this paper represents the productivity of labor and equals the income of labor providers, which is the lowest income paid to agents in the economy in equilibrium. In this subsection, we consider the labor earnings of the poorest workers as a proxy for A, specifically the share of the workforce that earns less than £1.25 per day. This share is likely a good proxy for the productivity of unskilled labor, i.e., A, because it is closely related to the average earnings of those with the least human capital. To begin, we note that 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 – 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 in this paper 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.[25] 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,[26] 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 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 relatively more human capital. Focusing now on China, Figure 8 show 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

[25]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.

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

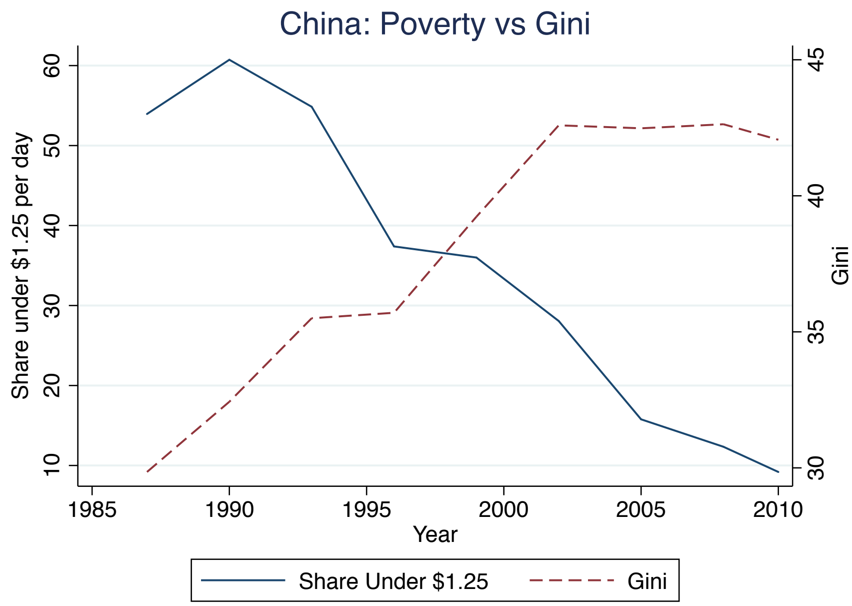


Figure 9: Poverty and Inequality in China. Source: United Nations

avoid the effects due to type B technological change, which we discuss in the next section.[27] 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 well.[28]

Whereas the typical narrative ascribes rising inequality within developing countries to the gains reaped by capital owners, our channel attributes it to rising incomes. More specifically, income that accrues to workers who are heterogeneous in their human capital and compete within occupations characterized by the performance of relatively similar tasks. 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 college graduates increased over 300 percent (see Deng and Li (2009)).

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

[28]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)

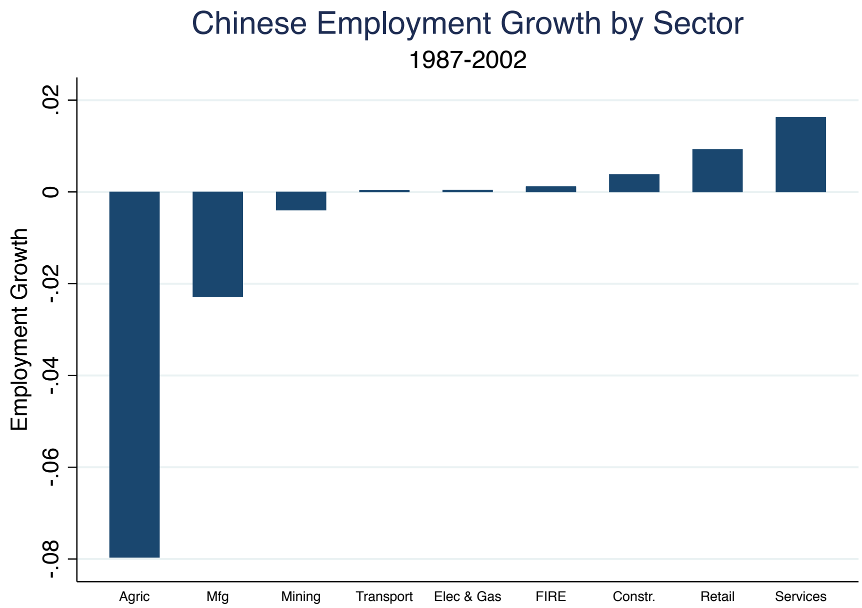


Figure 10: Percentage Point Change in the Chinese Employment Share. Source: United Nations

5.2. Evidence on Type B Technological Progress

Since type B technological change manifests as an outward shift in workers' scale of operation, the advent and spread of the Internet is an excellent test case for this phenomenon. To do this we focus on the U.S. in order to exploit detailed annual data on workers' hours and earnings. 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.[29]

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. In the language of the model these were affected and unaffected occupations, respectively. 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

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

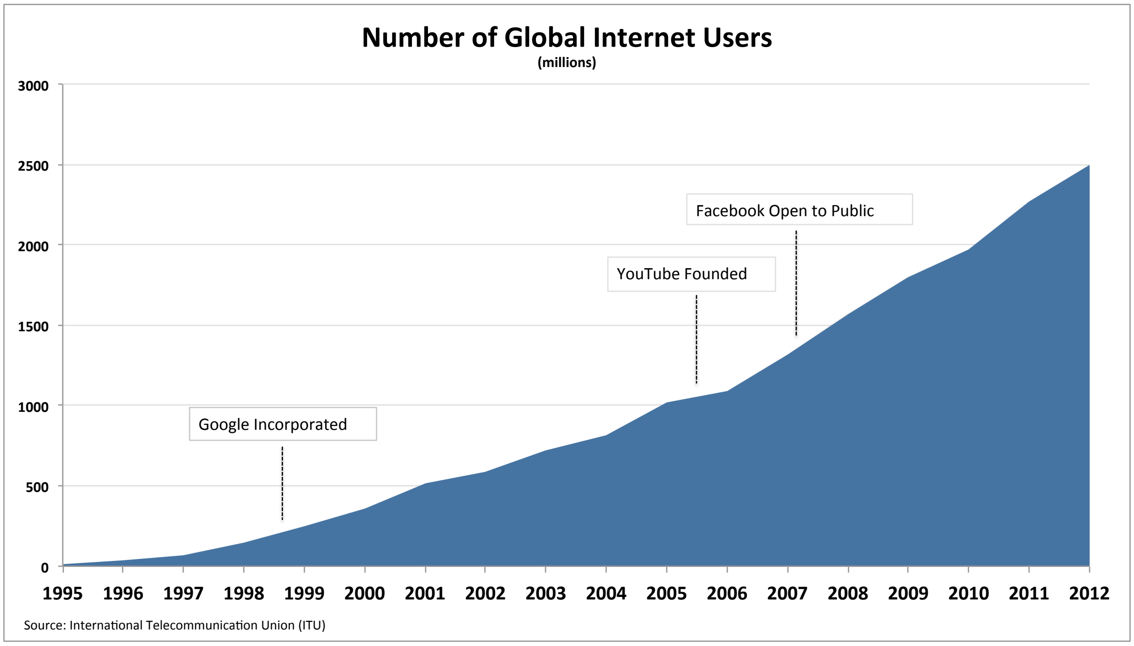


Figure 11: Growth in Global Internet Access

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.

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 11 – as well as the decade prior to this period, which will allow us to 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:

$$B_{it}^{Int} = \sum_j \left(IntShr_{jt} \times OccShr_{ijt} \right) \tag{26}$$

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.[30] Of course, the measure may not perfectly capture the extent to which occupational

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

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

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 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).

IRS, the Internet and Wage Inequality

In this subsection we test the implications of an increase in B for the employment and wage distribution within occupations. We begin with the effect on the income distribution where we test whether 1) lower-end workers see declining incomes as Proposition 3 indicates and 2) the change in a worker's income is rising in her initial income, as Proposition 4 indicates. To do this, 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

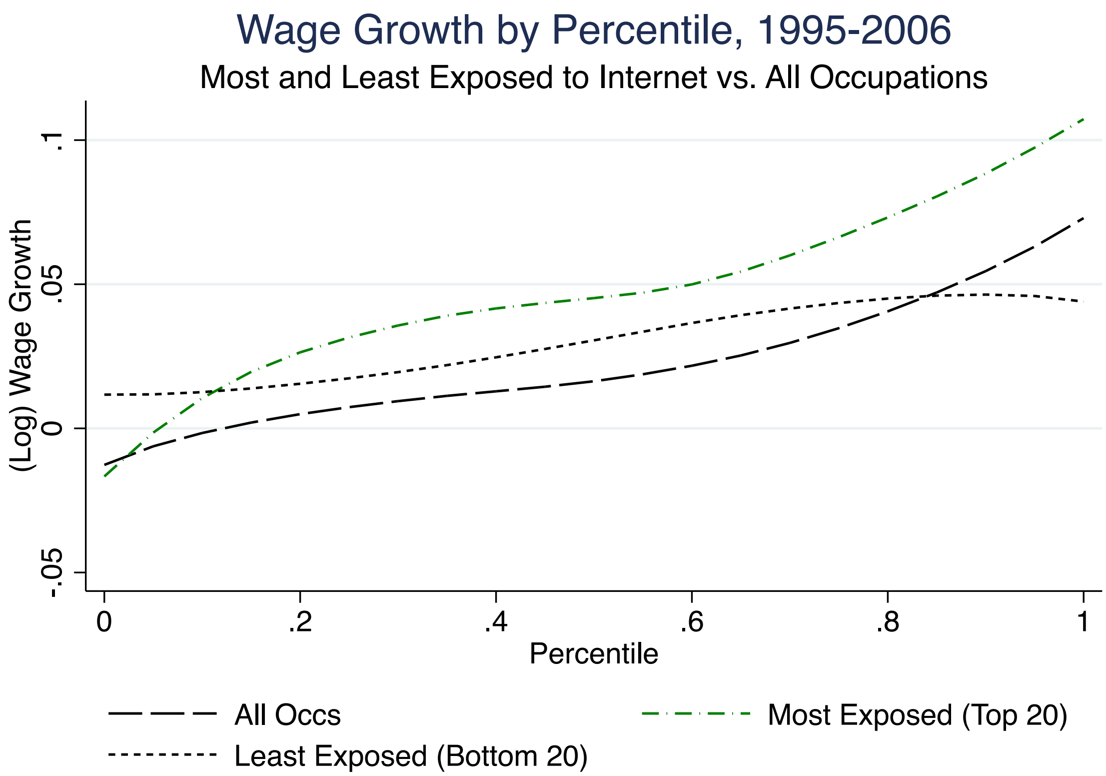


Figure 12: Wage Growth Across the Wage Distribution, Most and Least Affected by the Internet

serve as the relevant wage variation going forward.[31]

Figure 12 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 (26). The Figure shows that for the top 20 most affected occupations workers at the low end of the income distribution suffered a loss in income over the period, but this is *not* true of workers at the low end of the distribution within the least affected occupations, consistent with Proposition 3. At the same time, the relationship between income growth and initial income was much "steeper" over the period within the most affected occupations relative to the least affected occupations, as predicted by Proposition 4. In other words, income inequality grew to a much greater extent within these occupations.[32]

We next move toward a more formal test of Proposition 4 by exploiting information on all U.S. occupations, comparing the change in inequality within affected occupations relative to unaffected occupations due to the spread of the Internet. In doing so, we need to consider not only the implications of a rise in B for the *affected* occupations, but also the general equilibrium effects on

[31] 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.

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

the *unaffected* occupations, which, as noted in Section 4.3, work via two channels. First, aggregate income may rise which will raise income inequality due to the fact that workers with more human capital – who thus earn more – gain a relatively large share of the income growth across all occupations. However, this effect will be the same across both affected and unaffected occupations and so will be absorbed in the included time fixed effects. Second, the relative price of the output produced by affected occupations will fall, and this will reduce (increase) spending on the unaffected occupation output when the two outputs are substitutes (complements) for one another. We believe that the outputs of different occupations are, in general, gross substitutes on average, though there are certainly instances of complementarity among some sets of occupations. This implies that unaffected occupations will see falling inequality due to a rise in B. This effect strengthens our prediction that affected occupations should see rising inequality relative to unaffected occupations – in terms of a greater $d\Delta w/dw$ – due to an increase in B.

We formally test this prediction by estimating the following specification:

$$\triangle Wage_{qi,t:t+1} = c + \beta_1 \triangle B^{Int}_{it:t+1} + \beta_2 Wage_{qit} + \beta_3 \left(\triangle B^{Int}_{it:t+1} \times Wage_{qit}\right) + \sigma_i t + \delta_i + \alpha_t + \epsilon_{qit} \quad (27)$$

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.[33] 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. Again, Proposition 4 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 biased upward – i.e., we will over-estimate the differential impact of the Internet on our occupation

[33] 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.

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

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.[34] 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 Internet, with all specifications generating significant, positive coefficients on the interaction term,

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

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.

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.

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.

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

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:

$$\triangle Emp_{i,t:t+1} = c + \tau_1 \triangle B_{it}^{Int} + \gamma_i t + \alpha_t + \epsilon_{it} \tag{28}$$

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 D we present the results of regressions that are identical to (27) and (28) except they are estimated in long differences. The estimated effects are qualitatively the same, and much more precise.

6. Concluding Remarks

Technological changes of various types are constantly reshaping economies, generating winners and losers. In this paper we have explored the implications of two technological forces that have been important in recent decades. We have developed a model incorporating these technological changes, and considered the consequences of each type for the income distribution and career choice. Type A technological change enables workers to produce more output per unit of time while type B increases productivity by expanding workers' reach or "scale of operation" within certain human-capital-intensive occupations. The model's mechanisms are unique in two primary ways. First, although type A technological change is unskilled-biased, it increases income inequality among all workers. This is due to the fact that type A change increases aggregate income, and a greater fraction of this increase is captured by agents with relatively 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. In addition, the model predicts that type A change leads workers to move out of unskilled work into human-capital-intensive work. This is because the now-richer economy provides greater space for more people to apply their human capital in the provision of services, rather than working as unskilled labor.

Second, type B technological change directly impacts some occupations, raising income inequality within them. This occurs due to increased competition among workers, which drives workforce reallocation and redistributes revenue across the workers. This paper models type B technological change as an increase in the range over which the production technology exhibits Increasing Returns to Scale. 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, this generates two conflicting effects. On the one hand, the scale of operation for workers within the occupation increases, which benefits them. On the other hand, since this is true for all workers within the occupation, 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 relatively more human capital, who charge higher prices. The net effect is therefore to increase inequality within the occupation. Moreover, unlike the response to type A technological change, lower end workers are forced out of the human-capital-intensive occupations into unskilled work.

Thus, when both type A and type B changes are present the net effect on the margin between skilled and unskilled occupations is ambiguous. In contrast, both technological changes increase income inequality.

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.

We conclude by noting that there are undoubtedly many other types of technological changes, and each may have different implications for the economy. We believe that the technological forces that we consider here are important due to their near ubiquity and also because, though they arise for very different reasons, both imply rising income inequality, a common feature of most economies over recent decades. Importantly, the technological changes we explore here share a common implication which is that they may be more difficult for policy-makers to counter relative to institutional factors, such as the extent of unionization or tax policies.

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Appendix A. Proofs

Appendix A.1. Proof of Proposition 2

Proof. k is determined by equation (21). Differentiating with respect to B on both sides, we find

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

We further know that $d(^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}})/dk < 0$ 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/dB is negative.

On its RHS, $d(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}/dB > 0$ and $k-1 < 0$. Therefore, if $d[(1-k_0)(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}]/dB \leq 0$, 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 negative and thus $dk/dB > 0$. □

Appendix A.2. Proof of Proposition 3

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

Appendix A.3. Proof of Proposition 4

Proof. From (22), 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 (22),

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

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

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

The numerator is smaller than $1/(k-k_0)\cdot Ac/(A+Bc)^2$, while the denominator is greater than

$1/(k-k_0)+\frac{\rho}{1-\widehat{\rho}}(\log h_k)'$, 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 (A.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 A.4. Proof of Lemma 1

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

$$h_i^\rho/h_k^\rho\cdot[c-(A+Bc)\cdot\rho\cdot(\log h_k)'\cdot\frac{dk}{dB}]>c. \tag{A.2}$$

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

$$h_i^\rho/h_k^\rho\cdot[1-\frac{A}{A+Bc}\cdot\frac{\rho\cdot(\log h_k)'}{1+\rho(\log h_k)'(k-k_0)}]>1, \tag{A.3}$$

which is equivalent to (24). □

Appendix A.5. Proof of Lemma 2

Proof. We prove the lemma in three steps.

Step 1: If $h_1>1$, then

$$k-k_0<D(\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}(1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}. \tag{A.4}$$

Proof: k is determined by equation (21), 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, $H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}}h_k^{\frac{-\rho}{1-\widehat{\rho}}}=(\frac{H_k^{\rho-\widehat{\rho}}}{h_k^\rho})^{\frac{1}{1-\widehat{\rho}}}<(\frac{h_1^{\rho-\widehat{\rho}}(1-k)^{\frac{\rho-\widehat{\rho}}{\rho}}}{h_k^\rho})^{\frac{1}{1-\widehat{\rho}}}=h_1^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}}/h_k^{\frac{\rho}{1-\widehat{\rho}}}\cdot(1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}|_{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}\leq\frac{\rho}{1-\widehat{\rho}}\text{ and }h_1>1}<h_1^{\frac{\rho}{1-\widehat{\rho}}}/h_k^{\frac{\rho}{1-\widehat{\rho}}}\cdot(1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}$, which implies (A.4).

Step 2:

$$k < f(k_0, D \cdot (\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}). \tag{A.5}$$

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 (A.4) 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 (A.5) 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 A.6. Proof of Proposition 6

Proof. k is determined by equation (21). 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 A.7. Proof of Proposition 7

Proof. By (22), $\frac{dm_i}{dA} = \frac{h_i^\rho}{h_k^\rho} + (Bc+A)(-\rho)\frac{h_i^\rho}{h_k^{\rho+1}}\cdot h'_k\cdot\frac{dk}{dA} = \frac{h_i^\rho}{h_k^\rho}\cdot[1+(Bc+A)(\log h_k)'\cdot(-\rho\frac{dk}{dA})]|_{-\rho\frac{dk}{dA}>0 \text{ (by Prop. 5)}} > \frac{h_i^\rho}{h_k^\rho} \geq 1$. Moreover, by (22), $\frac{h_i^\rho}{h_k^\rho} = \frac{m_i+Bc}{A+Bc}$. 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. □

Appendix B. 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

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

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 (21), which, since $\widehat{\rho} = 0$, becomes

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

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

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

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

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

Then, (B.1) is equivalent to

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

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 (B.4), and thus inequality (B.1), holds true, which means that dm_i/dB decreases with m_i.

Appendix C. Internet Exposure Measure

Our measure of Internet exposure, B_{it}^{Int}, is constructed as in (26). 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 (26).

Appendix D. Wage and Employment Regressions, Long Differences

Here we present the results of regressions identical to (27) and (28) 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 D.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 D.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.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$