Technological Change and Within-Occupation Inequality

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Abstract: Much of the recent growth in U.S. income inequality has occurred *within* occupations. This paper documents new stylized facts with respect to this rise in within-occupation inequality, with a particular focus on the role played by Information and Communications Technologies (ICT). To explain these facts we develop a model of occupations in which heterogeneous workers within each occupation produce differentiated services. In the model, ICT enables a given quantity of worker output to be consumed or used to a greater extent. Formally, we model this as an increase in the limit up to which an occupation's production technology displays increasing returns to scale. This drives the workers with the least human capital out of the occupation and alters the incomes of the remaining workers such that the higher their initial income, the more they gain (or the less they lose), which leads to rising inequality. We also show that, via a general equilibrium effect, *any* technological change that raises aggregate income can also widen income inequality within some occupations. As a result, increased automation in the oil industry can contribute to a divergence of incomes among musicians.

JEL: J24, J31, O30, D33

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

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1. Introduction

Explaining the recent rise in income inequality has become an important objective within the economics literature. To explain rising inequality, studies have focused on variation across individuals,[1] industries,[2] geographic areas,[3], or firms[4] and have identified important roles for each. In this paper we focus on the role of occupations as a unit through which economic shocks that impact inequality may propagate, a topic that has thus far been overlooked in the economics literature.[5] To motivate our analysis, we introduce new stylized facts that highlight the importance of rising wage dispersion within occupations as well as the key role played by Information and Communications Technologies (ICT) in recent years. Importantly, and as we describe further below, these facts cannot be easily explained by existing models of technological change. For instance, models of Skill Biased Technical Change (SBTC) are not designed to explain the differential wage dynamics of workers who perform similar tasks, as workers often do within occupations. Furthermore, models of within- and between-firm inequality cannot easily explain the pattern of ICT-induced changes that we observe. With this in mind, we develop a theoretical model to explain the impact of ICT-driven technological shocks on the distribution of income within occupations.

To preview our empirical findings, Figure 1 decomposes the total rise in income inequality between 1990 and 2010 into within- and between-occupation components, where we see that both have been important. In addition, the Figure highlights the fact that the rise in within-occupation inequality can be mostly explained by a subset of occupations, namely those that were most exposed to internet sales over the period. In Section 3 below we formally define the measures used in Figure 1 and present econometric evidence in favor of a causal impact of the internet on rising within-occupation inequality. In particular, we focus on three new facts:

1. 40 percent of the rise in aggregate wage inequality over the period 1990-2010 occurred *within* occupations.
2. Nearly two-thirds of the within-occupation rise in inequality is due to the top ten percent of occupations that were most exposed to rising sales over the internet.
3. Occupations that were linked to relatively greater internet sales over the period experienced significantly slower employment growth.

[1] See Saez and Zucman (2016), Autor and Dorn (2013a), Autor, Levy and Murnane (2002), or Katz and Autor (1999) to name just a few representative papers.

[2] For example, see Autor, Katz and Krueger (1998).

[3] For example, see Goos and Manning (2007), Goos, Manning and Salomons (2009), Autor and Dorn (2013b) or Florida and Mellander (2016)

[4] For example, see Song, Price, Guvenen, Bloom and Von Wachter (2015) or Autor, Dorn, Katz, Patterson and Van Reenen (2017).

[5] One exception is the tasks-based approach in Fortin and Lemieux (2016). There are also notable exceptions within the sociology literature – e.g., see Mouw and Kalleberg (2010) or Kim and Sakamoto (2008).

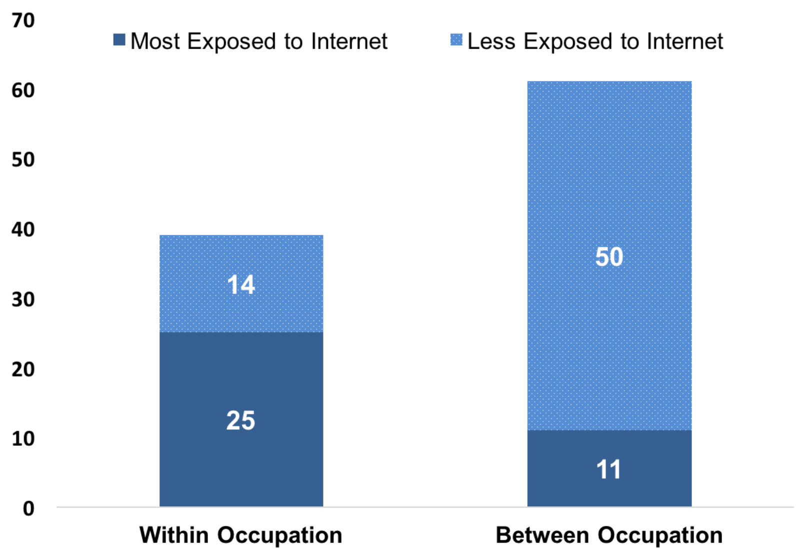

Figure 1: Contributions to Growth in U.S. Wage Inequality, 1990-2010

Thus, rising within-occupation inequality has been important and, at the same time, can be explained by the subset of occupations that has been most impacted by innovations in ICT. Importantly, the first two facts imply that over a quarter of the recent rise in *aggregate* wage inequality can be explained by these types of occupations, and yet the facts cannot be jointly explained by existing models of technological change. For instance, consider travel agents, whose share of U.S. employment has halved over the past two decades (consistent with Fact 3), even as the average travel agent has seen a 14 percent increase in their real wage over the period and "superstar" travel agents have thrived (Fact 1),[6] an outcome overwhelmingly achieved by exploiting internet-based sales strategies (Fact 2).[7]

With this in mind, we present a model that demonstrates that ICT progress may simultaneously increase income inequality, and reduce employment, within occupations. We show that this is due to rising competition within occupations, which generates workforce reallocation and selection into and out of the occupation.

The model highlights a particular feature of new ICT, namely that ICT often increases the size of the market – which we will refer to as the "scale of operation" – for *all* workers within certain occupations. For example, the advent of television and, more recently, the internet has vastly expanded the potential number of viewers for football games – i.e., these technologies have vastly

[6]Source for employment and wage statistics: Bureau of Labor Statistics, Occupational Employment Statistics Survey, 1997 and 2016

[7]For instance, see "How the Internet Created the Superstar Travel Agent": https://www.forbes.com/sites/douggollan/2015/03/27/how-the-internet-created-the-superstar-travel-agent-2

expanded the scale of operation for footballers. Similarly, the internet has created new markets and outlets for producers of furniture and academic research. And indeed, the importance of workers' 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. This literature, however, has not formally analyzed the effects of an increase in the scale of operation, as we do here.

Formally, we consider a continuum of agents with equal endowments of unskilled labor but heterogeneous endowments of human capital. They choose to subsist either by employing their labor, or by employing their human capital and thereby becoming a "professional", for which the quality of their output depends on the size of their human capital endowment.[8] 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, whereas the services provided by individual professionals are differentiated. We motivate this setup by noting that 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, professionals produce differentiated output and thus compete via monopolistic competition.

We assume that after committing her time to supply human capital rather than labor – which entails the payment of a fixed cost – a professional hires labor to produce her variety of services at constant returns to scale up to the technological limit, denoted B. Thus, a professional's aggregate production technology displays Increasing Returns to Scale *up to some Limit* (which we denote IRSL), with the limit given by 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.[9] Technological progress that increases B thus increases the maximum, *potential* scale of operation for all professionals.[10] The primary technological shock that we focus on – i.e., our proxy for innovations in ICT – is reflected in an increase in B for some occupation. In addition, the productivity of labor, measured by the quantity of the subsistence good produced per unit of labor, is denoted by A. We show that an additional feature of our model is that, in general equilibrium, any increase in labor productivity also generates rising inequality among professionals.

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

[9] For example, it is costly to create a live music performance (i.e., there is a fixed cost), but it costs little to admit an additional person into the theater to hear it up to the point that the theater is filled; the capacity of the theater thus defines the limit of IRS for the musicians. 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.

[10] However, this does not necessarily increase the *actual* scale of operation for a particular professional. For example, the internet may enable a singer to access several hundred million potential customers, but the singer will likely be unable to sell to each of these people.

We show that an increase in either B or A will widen inequality between professionals within an occupation, but via very different mechanisms. Consider first an increase in B, the IRS limit, which is our primary variable of interest. On the one hand, each professional within the occupation can sell more, which benefits them. On the other hand, since the capacity of all professionals increases each of them faces fiercer labor market competition. Whereas the increase in competition is the same for all professionals, the expansion in capacity delivers greater benefits to those who have more human capital and are therefore able to charge a higher price for their stream of services. As a result, more talented professionals reap greater gains from a given increase in B, which therefore raises income inequality between professionals. Now consider an increase in A. This increases the productivity of labor hired by professionals as well as the wage paid to labor, which results in no net effect on the marginal cost, nor the profit, associated with professionals' production of their stream of occupational services. Nevertheless, an increase in A widens income inequality between professionals due to a general equilibrium effect, with the intuition 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. This again increases income inequality.

While an increase in either B or A will raise income inequality, the consequences for selection into and out of occupations – what can be thought of as the "career margin" – are quite different. First, an increase in A induces more agents to exploit their human capital relative to their labor, and thereby select into a professional occupation, leading to a greater variety of differentiated output. We note that this effect is consistent with the long-run historical shift away from labor-intensive work and toward human-capital-intensive work, such as the long-run growth in the supply of artists, writers, sportsmen, comedians, etc. On the other hand, an increase in B drives agents *out of* human-capital-intensive professional work by intensifying competition between professionals. For example, the popularity of television makes it difficult to earn a living as a local comedian, while the expansion of the internet has reduced opportunities for travel agents. This result is thus consistent with a range of anecdotal observations on the effects of ICT advancement, and is also consistent with the employment declines among certain occupations that we document in Section 3.

The paper proceeds as follows. Section 2 places our paper within the existing literature. Section 3 documents stylized facts with respect to changing within-occupation inequality. Sections 4 and 5 present our theory of technological change. Section 6 suggests a further link to observed trends in inequality. Section 7 provides concluding remarks.

2. The Literature

The general theme of our paper, namely that technological change may increase income inequality, fits within a large strand of literature that approaches the topic from a variety of perspectives. As noted, the dominant theoretical argument in this literature is the theory of Skill-Biased Technical Change (SBTC). Relative to SBTC and its extensions,[11] our paper presents a new mechanism through which technological changes affect the income distribution, in particular by focusing on technological change that differentially affects workers who are engaged in *the same type of work*.[12] This is important in light of the evidence we discuss in Section 3, as well as other recent empirical evidence that within-occupation variation in income is important; for example, see Helpman, Itskhoki, Muendler and Redding (2012) for Brazil.

More recently, Song et al. (2015) show that two-thirds of the rise in income inequality between 1978 and 2013 has occurred between firms. They further show that this is entirely due to changes in the composition of workers across firms, rather than due to rising firm average pay. Our finding of an important role for an occupation's exposure to internet sales[13] suggests that the phenomena we seek to explain are in important dimensions distinct from Song et al. (2015), a point we return to in Section 3. In other words, it is not straightforward to link changes in the sorting of workers across firms to rising occupational exposure to internet sales, though we do not claim that there can be no link. We also show that the occupations that have recently contributed to rising within-occupation inequality experienced relatively slow employment growth over the period, consistent with the mechanisms we highlight and with a specific role for new ICT. Our explanation is thus consistent with, but clearly distinct from, those authors' findings.

The role of scale of operation (or market access) as it relates to the return to skill has long been noted in the literature that seeks to explain certain features of the top of the income distribution, i.e., the earnings of "superstars"; for example, see Rosen (1981), Rosen (1983), Gabaix and Landier (2006), and Egger and Kreickemeier (2012), and see Neal and Rosen (2000) for a summary. However, this literature is mainly concerned with the level of income inequality for a *given* level of technology,

[11] 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) 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. Recently, Acemoglu and Autor (2011) have extended the standard SBTC framework to endogenize the matching of skills to tasks.

[12] The differential effects in our paper arise from differences in workers' human capital endowments, similar to 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 matches features of the U.S. wage distribution over the past four decades in a simulation exercise, though there is no attempt to explain growth in within-occupation inequality.

[13] Note that we focus explicitly on internet sales, not the use of the internet in a job more generally which could plausibly drive increased assortative matching.

and in particular with 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 impact of an increase in the scale of operation. In contrast, we model the scale of operation as the limit within which the production technology displays IRS, and this modeling approach is new to the literature. With this approach in hand, we articulate a new mechanism in the form of competition and workforce reallocation to explain rising within-occupation inequality. In addition, we also study selection into and out of occupations, i.e., the career choice margin, between providing labor and becoming a low-end professional (who are certainly not superstars), whereas this margin is absent in that literature.

Our model has some of the flavor of Melitz (2003),[14] though the two papers are concerned with different issues.[15] Both papers feature monopolistic competition with CES preferences, IRS, and agent heterogeneity. However, in our paper IRS operates up to some finite limit, whereas in Melitz (2003) this limit is infinity. As a result, while an increase in B in our paper might be regarded as parallel to an increase in the number of trading partners in Melitz (2003) (i.e., both reflect an increase in market size), the mechanism whereby this increase drives re-allocation is different. In Melitz (2003), it works through the factor market but it does not alter the price of any variety in the product market. In contrast, in our paper, the cost of the factor, which is labor, is unchanged, and the increased competition works through the product market, lowering the price of all varieties. On the other hand, this effect on the product market 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 B reduces the number of varieties, as an increased number of trading partners does in Melitz (2003).

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, Garicano and Rossi-Hansberg (2014) extend Lucas Jr (1978) in order to demonstrate the implications of ICT innovation for the income distribution, which they model as a reduction in the rate at which the marginal return to the labor working for a manager falls. This does not intensify competition between managers and no manager loses due to this change. In contrast, an increase in the IRS limit in our model generates effect by increasing competition between workers, which consequently incurs losses for the lowest earners. Other work includes Jones and Kim (2012) who endogenize the Pareto income distribution

[14]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).

[15]Specifically, our paper is concerned with the effects of technological progress on the income distribution in a closed economy, while Melitz (2003) is focused on the relationship between exporting and aggregate productivity in an open economy.

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.

3. Empirical Patterns

In this section we exploit U.S. occupational data over the last three decades and document features of the change in wage inequality within and between occupations. Throughout, we use data on wages and employment from the U.S. Census (decadal 1990-2000) and American Community Survey (ACS) (for 2010) over the years 1990 to 2010.[16] Our unit of interest is the occupation, and we adopt a consistent definition of occupations across datasets using the definitions from Autor and Dorn (2013a).

We document the three facts introduced above, first descriptively and, second, via a regression approach. To reiterate, the three facts are: 40 percent of the rise in aggregate wage inequality over the period 1990-2010 occurred *within* occupations; nearly two-thirds of the rise in within-occupation inequality can be explained by the occupations that were most exposed (top ten percent) to rising internet sales; these most-exposed occupations saw significantly slower employment growth relative to other occupations, on average, over the period.

In addition, more suggestive empirical evidence in support of the model's mechanisms is relegated to a section that follows the description of the model.

3.1. Decomposition of Wage Dispersion

We begin by decomposing aggregate log wage dispersion into within- and between-occupation components separately for 1990, 2000 and 2010. Formally, we calculate:

$$\frac{1}{N_t}\sum_i (w_{it}-\bar{w}_t)^2 = \frac{1}{N_t}\sum_l \sum_{i\in l}(w_{it}-\bar{w}_{lt})^2 + \frac{1}{N_t}\sum_l N_{lt}(\bar{w}_{lt}-\bar{w}_t)^2 \tag{1}$$

where workers are indexed by i and the year by t; l represents occupations; N_{lt} and N_t represent the number of workers in each occupation and overall; and w_{it}, $\bar{w}_{lt}$ and $\bar{w}_t$ are the log worker wage, the average log occupational wage, and the overall average wage. In using the log wage we ensure

[16] The data come from IPUMS (see Ruggles, Alexander, Genadek, Goeken, Schroeder and Sobek (2010)). We deal with top-coding in the manner described by Bakija, Cole and Heim (2010), though our results are also robust to excluding top earners. Consistent with the literature, we restrict the sample to full-time workers between 18 and 65.

	Overall			Most vs. Least Exposed to Internet Sales			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Year	Total Wage Dispersion	Within-Occupation	Between-Occupation	Within (Most Exposed)	Within (Least Exposed)	Between (Most Exposed)	Between (Least Exposed)
1990	0.298	0.223	0.075	0.028	0.195	0.013	0.062
2000	0.322	0.233	0.089	0.032	0.200	0.014	0.075
2010	0.377	0.254	0.123	0.048	0.206	0.022	0.101

Table 1: Wage Dispersion Within and Between Occupations, 1990-2010

the values are independent of the wage units. The first term on the right hand side reflects the within-occupation component of wage inequality.

Table 1 reports the results. The first three columns of the table highlight the overall contributions of within- and between-occupation inequality. First, throughout the period the contribution of within-occupation inequality to aggregate inequality in any particular year is large relative to the between component. Furthermore, 40 percent of the rise in aggregate inequality between 1990 and 2010 was due to a rise in within-occupation inequality (Fact 1). We can decompose total log wage dispersion further by noting that the within term in (1) is the sum across individual occupations, and so the contribution of different subsets of occupations can be easily separated out. As it turns out, most of the rise in within-occupation inequality was due to a particular subset of occupations, namely those most affected by the internet. To see this, we construct a measure of the extent to which the output of each of 330 U.S. occupations was associated with internet sales in 2000 and 2010, setting 1990 to zero for all occupations. We denote the measure as B^{int} in order to link it conceptually to the market size measure discussed in the Introduction and that will be a focus of the theoretical section. We define the measure in the following way:

$$B_{it}^{int} = \sum_j \left(IntShr_{jt} \times OccShr_{ij,1990}\right) \tag{2}$$

where $IntShr_{jt}$ is the share of industry j sales in year t that was made over the internet and $OccShr_{ij,1990}$ is the share of occupation i's total hours employed in industry j in 1990.[17] Thus, the latter term reflects the importance of each industry, in terms of labor hours, to each occupation in a period in which the internet was absent, where we use a pre-period occupational structure in order to avoid incorporating effects due to endogenous changes in the composition of occupations caused by the internet. The former term then captures the extent to which firms within each industry

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

Top 10		Bottom 10	
1	Financial services sales occupations	**327**	Legislators
2	Motion picture projectionists	**328**	Clergy and religious workers
3	Cabinetmakers and bench carpenters	**329**	Inspectors of agricultural products
4	Editors and reporters	**330**	Welfare service aides
5	Furniture and wood finishers	**331**	Postmasters and mail superintendents
6	Typesetters and Compositors	**332**	Meter readers
7	Other financial specialists	**333**	Mail and paper handlers
8	Broadcast equipment operators	**334**	Hotel clerks
9	Computer Software Developers	**335**	Judges
10	Actors, directors, producers	**336**	Sheriffs, bailiffs, correctional institution officers

Table 2: Top and Bottom 10 Occupations by Exposure to Internet Sales

sell their output over the internet.[18] Table 2 lists the top 10 (left column) and bottom 10 (right column) occupations in terms of their exposure to internet sales according to this measure.

The last four columns of Table 1 once again decompose total log wage dispersion in each year into the within and between components, but then decompose each of these into two further sets of occupations reflecting 1) the top 10 percent of occupations according to measure (2) and 2) all other occupations. Comparing columns (2) and (4), we see that 65 percent of the rise in within-occupation wage inequality between 1990 and 2010 is due to the set of occupations that were most exposed to internet sales (Fact 2).

Finally, employment growth among the top ten percent of occupations most linked to internet sales was 7 percent over the period, rising from about 7 to 7.5 million workers, significantly slower than the 36 percent average employment growth associated with other occupations (Fact 3).

3.2. Regression Approach

In this section we provide further evidence regarding the impact of the internet on within-occupation wage dispersion. To do this we exploit the natural experiment generated by the growth in use of the internet in the mid-1990s, which differentially exposed workers to a rise in market access for their services over subsequent years. Due to the internet, some workers, such as actors and writers, now face a potential market size that is many millions of consumers larger than it was in 1990, while others, such as bus drivers, face approximately the same set of potential consumers as they did in 1990.

[18] Of course, the measure may not perfectly capture the extent to which occupational services are linked to internet sales. For instance, even within an industry that sells a substantial amount over the internet, some occupations may be specialized in brick-and-mortar sales, while others are focused on internet sales. Furthermore, our analysis below will focus in part 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.

We exploit this differential exposure to potential sales over the internet by estimating the following specification:

$$\triangle WageGap_{i,t:t-1} = c + \beta_1\big(\triangle B^{int}_{i,t:t-1}\big) + \beta_2 CompUse_{i,1989} + WageGap_{i,80-90} + \epsilon_{it} \qquad (3)$$

where we follow recent convention by defining the change in wage inequality, $\triangle WageGap_{i,t:t-1}$, as the change in the gap between the 90th and 10th percentiles of the log wage distribution for each occupation i or, alternatively, the 90-50 log wage gap, where we stack changes over the periods 1990 to 2000 and 2000 to 2010. Importantly, the wage variation we exploit has been cleaned of variation due to age, age squared, sex and level of education in a "first stage" regression; in other words, we effectively control for changes in the composition of workers within occupations. We also clean the wage of industry variation (i.e., include industry fixed effects in the first stage), thereby controlling for differences across industries in the evolution of the wage structure. In addition, in some specifications we control for differential pre-period trends (1980 to 1990) in the wage gap, denoted $WageGap_{i,80-90}$. Standard errors are clustered at the occupation level.

In our strictest specifications we also control for the differential use of computers across occupations in 1989 ($CompUse_{i,1989}$), several years prior to the spread of the internet. Specifically, we control for the share of hours worked in an occupation by workers who use a computer in order to address the possibility that computer use is a key omitted variable in the specification.[19] In other words, the relationship between the change in internet sales within an occupation and rising inequality may be due to the direct impact of increased computer use on both wage inequality and rising internet sales. By controlling for computer use in 1989 we absorb variation in the prevalence of computer use across occupations that is unrelated to (future) internet sales.[20]

Noting that the results are suggestive, and not definitive, Table 3 presents the estimates. In columns (1)-(6) we see that rising internet sales are associated with a widening wage gap, both across the 90-10 distribution as well as the 90-50 distribution. Aside from a lack of statistical significance in column (6), these effects hold across specifications, indicating that the effects are not solely driven by predicted computer use or pre-trends in the wage distribution. The economic magnitudes are also important: the estimates imply that the increase in occupational exposure to internet sales over the period explains 39 percent of the rise in the 90-10 wage gap and 26 percent of the rise in the 90-50 gap.[21]

[19]We obtain these data from the Current Population Survey computer use supplement, 1989.

[20]The shortcoming of this control is that it likely does not perfectly predict future computer use in an occupation, and the unexplained portion of future computer use may be correlated with both rising wage inequality and internet sales. At the same time we note that some of this additional variation will likely be absorbed by the pre-trends in the wage gap.

[21]The mean of the internet exposure measure rose from 0 to 0.05 over the period. Multiplied by the coefficient in column (3) from Table 3 gives a value of 0.014, which is 39 percent of the total rise in the 90-10 wage gap over the

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ 90-10 Log Wage Gap			**Δ 90-50 Log Wage Gap**			**Δ Log Employment**		
$\Delta InternetSales$	0.354***	0.315*	0.270*	0.142**	0.113**	0.091	-0.023***	-0.021**	-0.018**
	(0.155)	(0.167)	(0.141)	(0.062)	(0.045)	(0.073)	(0.007)	(0.010)	(0.008)
$CompUse_{1989}$		0.064***	0.063***		0.026**	0.024*		0.044*	0.051*
		(0.018)	(0.018)		(0.013)	(0.014)		(0.022)	(0.028)
$WageGap^{90-10}_{1980-1990}$			-0.225***						-0.356***
			(0.084)						(0.061)
$WageGap^{90-50}_{1980-1990}$						-0.073			
						(0.101)			
Observations	642	584	584	642	584	584	642	584	584

Notes: Dependent variables are the stacked change in the 90-10 log wage gap, 90-50 log wage gap and log employment over 1990-2010. In a first-stage regression, wage variation is cleaned of variation in age, age squared, sex, education, and industry. Exposure to internet sales at the occupation level is defined as described in Section 3.1. Computer use in 1989 is obtained from the computer use supplement of the 1989 Current Population Survey. The wage gap controls are the pre-period changes in the wage gap (between 1980 and 1990) for the 90-10 and 90-50 gaps, respectively. Standard errors are in parentheses and are clustered at the occupation level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Impact of the Rise in Internet Sales on Within-Occupation Inequality, 1990-2010

In columns (7), (8) and (9) we estimate a specification identical to (3) except with the (stacked) change in log hours worked as the dependent variable.[22] Here we find that increased internet sales are associated with an absolute decline in occupational employment. We note that this is an even stronger result than suggested by the descriptive facts, which showed slow, but positive, growth for the subset of occupations most impacted by internet sales. Since employment growth was positive, on average, over the period – i.e., the effect due to increased exposure to internet sales *offset* overall employment growth – we note that the negative effect estimated here is on the order of 10 percent of the observed, positive employment growth.

In summary, the results indicate that the rapid rise in market access due to the spread of the internet has been associated with an increase in within-occupation inequality, as well as declining employment for the most impacted occupations. In the next section we present a model that can explain these dynamics.

4. 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 subsist on their labor endowment (i.e., muscles) or else on their

period. A similar calculation leads to the value with respect to the 90-50 gap.

[22] In this case we control for the pre-trend in the 90-10 wage gap, but the results are nearly identical to controlling for the pre-trend in the 90-50 gap.

human capital (i.e., brains).[23] 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, as will be made clearer later.

Labor is used for producing both a subsistence good (such as food), which is used as numeraire, and entertainment services. 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

$$Y = AL.$$

Hence A represents the productivity of (unskilled) labor.

The production of entertainment services requires two factors, human capital and labor. We assume that human capital only affects the quality of the output and abstract from the effect of human capital on quantity. If an agent chooses to subsist on her human capital endowment and provide entertainment services, then her human capital impacts the quality of the entertainment services in two ways. First, some aspects of her human capital are unique, and thus so are the services that she provides (for instance, Jay-Z versus Madonna), as in the canonical Krugman (1979) model. 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. We abstract from the effect of human capital on output quantity by assuming that all agents have the same production function. Specifically, if an agent hires L units of labor, the output of her variety is

$$y = \left\{ \begin{array}{c} \frac{A}{c}L, \text{ if } L \leq \frac{c}{A}B \\ B, \text{ if } L > \frac{c}{A}B \end{array} \right\}, \tag{4}$$

where $c > 0$ is a constant. Thus, if an agent decides to use his time to supply human capital rather than labor, thereby providing a variety of entertainment services, he can subsequently hire labor to produce output at constant returns to scale up to the limit B. According to this production function, a unit of labor produces A/c units of output, which means a unit of output needs c/A units of labor. Let w denote the wage of labor and F the opportunity cost of the agent's career

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

choice (namely, time).[24] Then the cost function associated with producing entertainment services is

$$C(y) = \left\{ \begin{array}{c} F + w\frac{c}{A}y, \text{ if } y \leq B \\ \infty, \text{ if } y > B. \end{array} \right\}. \tag{5}$$

The marginal cost of production (up to B) is wc/A and stays constant. Due to the existence of fixed costs F, the average cost decreases with output y until $y > B$. Hence, if $B = \infty$, the production of entertainment services displays a typical instance of Increasing Returns to Scale (IRS). However, if $B < \infty$, then production of services displays IRS only up to the limit B, which is thus IRS up to some limit, which we denote as IRSL. The primary modeling innovation presented here is the introduction of this limit of IRS, denoted B. We use this B to represent the maximum scale of operation for an entertainer – for example, the capacity of the theater in which a musician performs.[25]

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[26]

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

where $\mu > 0$ measures the relative importance of the subsistence good in the agent's utility function; $\widehat{\rho} < 1$ measures the substitutability or complementarity (as we allow $\widehat{\rho} < 0$) between the subsistence good and entertainment services; and $\rho \in (0,1)$ measures the substitutability between one entertainment service and another. We 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, entertainment services provided with higher human capital deliver greater value to consumers, as noted above.

Let p_i denote the price of variety i of entertainment services and let m_j denote the income of agent j. Then, the consumption decision that the agent faces is

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

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

[25] Alternatively, if the services that an agent provides consist of the management of a firm, then B represents the size of the firm (see footnote 9 above).

[26] Throughout the paper the notation "di" is omitted to simplify notation.

The agent's demand for the subsistence good and entertainment services are, respectively:[27]

$$
\begin{aligned}
s &= m_j \cdot \frac{1}{1+\mu^{1/(\widehat{\rho}-1)}P^{\widehat{\rho}/(\widehat{\rho}-1)}} && (6) \\
e_i &= m_j \cdot f(P,\mu) \cdot h_i^{\rho/(1-\rho)} p_i^{-1/(1-\rho)}, && (7)
\end{aligned}
$$

where P is the general price of entertainment services per unit of quality, defined as

$$
P := \Big(\int_E (p_i/h_i)^{\rho/(\rho-1)} \Big)^{(\rho-1)/\rho}, \tag{8}
$$

and

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

According to this optimal consumption plan, the demand for a variety is proportional to the agent's income. Hence, the aggregate demand for a particular variety that charges price p and is of quality h (equal to the human capital endowment of the provider) is

$$
D(p;h) = M \cdot f(P,\mu) \cdot h^{\rho/(1-\rho)} p^{-1/(1-\rho)}, \tag{9}
$$

where

$$
M := \int_{[0,1]} m_j \tag{10}
$$

is aggregate income. Note that $D'_h > 0$ – that is, given some price, the demand for a higher-quality variety is greater because consumers derive greater value from it.

If an agent with human capital h chooses to supply labor and produce the subsistence good, she 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 (5), 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 her human capital and produce her variety of services, the demand for her services will be given by (9), where she takes the aggregate variables P and M as given. She then sets the price of her services by solving the following decision problem:

$$
m(h) = \max_p (p-c)D(p;h), \text{ s.t. } D(p;h) \le B \tag{11}
$$

[27] 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.

An agent with human capital h chooses to provide entertainment services instead of supplying labor only if

$$m(h) \geq A \tag{12}$$

From the envelope theorem and (11), $m'(h) > 0$. There thus exists a threshold $k \in [0, 1]$ such that agent i chooses to provide entertainment services if and only if $i \geq k$, where k is pinned down by

$$m(h_k) = A.^{28} \tag{13}$$

If $i < k$, agent i earns wage $w = A$, and if $i \geq k$ 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 general price for entertainment services, from (8), is given by

$$P = \Big(\int_k^1 (p_i/h_i)^{\rho/(\rho-1)} \Big)^{(\rho-1)/\rho}, \tag{14}$$

and aggregate income is

$$M{=}kA + \int_k^1 m(h_i). \tag{15}$$

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

(i) P is given by (14), where p_i solves (11) with $h = h_i$;

(ii) agent i chooses to supply labor if and only if $i < k$ where k is determined by (13);

(iii) Aggregate income is given by (15).[29]

5. Equilibrium and Technological Change

In this section we prove the existence of a unique equilibrium, find the equilibrium income of each agent, and then consider comparative statics with respect to B. In the final subsection we also consider the effect of an increase in A on the income distribution. We first focus on the case in which the capacity constraint, $D(p; h) \leq B$, is binding for all agents who choose to be entertainers, such that their profit is $(p - c)B$. This effectively requires B to be sufficiently small and an exact

[28] 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 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.

[29] 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.

condition is provided in Subsection 5.3. 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 subset of entertainers. Of course, if it is not binding for any agents then an increase in B will have no effect.

To find the equilibrium income distribution, we proceed in two steps. First, we find the income of each agent, given that the identity of the marginal entertainer is k. Second, we find an equation that determines k and show that the equation has a unique root for k.

Two observations immediately follow from the fact that the capacity constraint is binding for each entertainer. First, the supply of each variety of services is the same, B. As a result, each agent, whatever his income, consumes the same quantity of each variety; put differently, his consumption of entertainment services is a multiple of a bundle that consists of one unit of each variety. To see this, observe that according to (7) any agent's consumption of variety i is proportional to his income and this proportion is the same across agents, denoted by x_i. Our claim is equivalent to $x_i = x_j$ for any two varieties i and j. To see that this is true, note that the aggregate consumption of variety i is Mx_i and equals the aggregate supply, B. It follows that $x_i = B/M$ for any variety i.

Second, with $D(p; h)$ given by (9), the binding capacity constraint, $D(p; h) = B$, implies that the price of variety i is:

$$p_i = \Big(\frac{Mf(P, \mu)}{B}\Big)^{1-\rho} h_i^\rho. \tag{16}$$

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 one 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. It follows that the aggregate spending on variety i, namely $p_i B$, is a fraction of h_i^ρ / H_k^ρ of the aggregate spending on all the entertainment services $\int_k^1 p_j B$, where

$$H_k := \Big\{ \int_k^1 h_i^\rho \Big\}^{\frac{1}{\rho}} \tag{17}$$

is the aggregate quality of the aforementioned bundle which consists of one unit of each variety.[30] Moreover, for any $i \geq k$, $p_i/p_k = h_i^\rho / h_k^\rho$. Agent k, the marginal entertainer, obtains profit A as she is indifferent between the two occupational choices. That is, $p_k \times B - Bc = A$, or

$$p_k = A/B + c. \tag{18}$$

[30] In this aggregation, as in (16), the quality of each variety is raised to power $\rho < 1$ because one variety of entertainment services is not a perfect substitute for another.

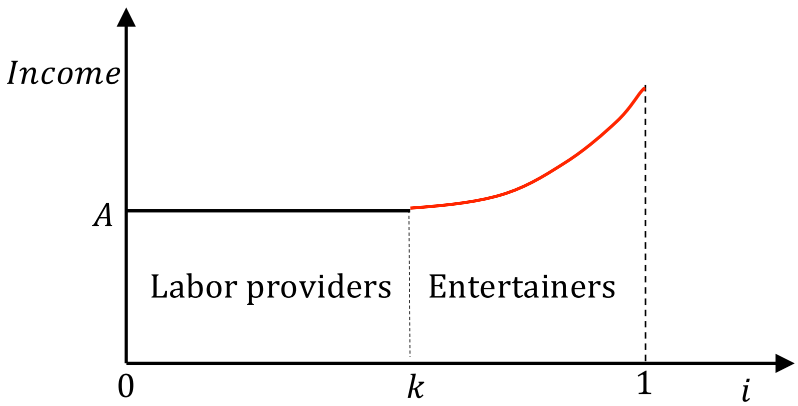

Figure 2: The Equilibrium Income Distribution

It follows that $p_i = (A/B + c) \times h_i^\rho / h_k^\rho$ and the income of agents $i \geq k$ is $m_i = (p_i - c)B = (A + Bc)h_i^\rho / h_k^\rho - Bc$. We know that agents $i < k$ choose to provide labor and earn $m_i = A$. Putting these together, the equilibrium income distribution is:

$$m_i = \left\{ \begin{array}{l} A \text{ if } i < k \\ (Bc + A)\frac{h_i^\rho}{h_k^\rho} - Bc \text{ if } i \geq k \end{array} \right\} \tag{19}$$

This income distribution is illustrated in Figure 2.[31]

We now move on to determining k via the market clearing condition for the subsistence good. We first establish that aggregate spending on this good is $BH_k(\mu P)^{\frac{1}{1-\hat{\rho}}}$. To see this, note that from (6) it follows that the aggregate income spent on the subsistence good is $M \times \left[1 + \mu^{1/(\hat{\rho}-1)} P^{\hat{\rho}/(\hat{\rho}-1)}\right]^{-1}$. To find the aggregate income M, observe that with the price of each variety given by (16), the price index, from (14), is

$$P = \left(\frac{Mf(P, \mu)}{B}\right)^{1-\rho} H_k^{\rho-1}. \tag{20}$$

With $f(P, \mu) = P^{\frac{\rho-\hat{\rho}}{(1-\rho)(1-\hat{\rho})}} / \left(\mu^{\frac{1}{1-\hat{\rho}}} + P^{\frac{\hat{\rho}}{\hat{\rho}-1}}\right)$, it follows that

$$M = BPH_k \times \left[1 + \mu^{\frac{1}{1-\hat{\rho}}} P^{\frac{\hat{\rho}}{1-\hat{\rho}}}\right]. \tag{21}$$

[31] 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.

Therefore, aggregate spending on the subsistence good is

$$BPH_k \times \left[1 + \mu^{\frac{1}{1-\widehat{\rho}}} P^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}\right] \times \left[1 + \mu^{1/(\widehat{\rho}-1)} P^{\widehat{\rho}/(\widehat{\rho}-1)}\right]^{-1} = BH_k(\mu P)^{\frac{1}{1-\widehat{\rho}}}$$

Next, we find the aggregate supply of the subsistence good. A mass $1-k$ of agents provide services, each demanding Bc/A units of labor as input. The total labor supply is k. Thus, $k - \frac{c}{A}B \times (1-k)$ agents work to produce 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.

Market clearing for the subsistence good thus implies:

$$BH_k(\mu P)^{\frac{1}{1-\widehat{\rho}}} = (A+Bc)(k-k_0). \tag{22}$$

This equation contains P, an endogenous variable. To determine k, we exploit an additional connection between P and k, as follows. Using (20) to cancel $\left(\frac{Mf(P,\mu)}{B}\right)^{1-\rho}$ in (16), we find $p_i = PH_k^{1-\rho}h_i^{\rho}$ for any $i \geq k$, in particular when $i = k$. At the same time, in (18) we found $p_k = A/B + c$. Therefore,

$$PH_k^{1-\rho}h_k^{\rho} = \frac{A}{B} + c. \tag{23}$$

Solving for P, substituting it into (22) and rearranging, we arrive at a single equation that pins down k in equilibrium:

$$\mu^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}} \times (A/B+c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}} = k - k_0 \tag{24}$$

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 aggregate spending on the subsistence good conditional on the marginal entertainer being agent k, also measured in units of his revenue. 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 aggregate spending on entertainment services 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.[32]

For the non-Cobb-Douglas case, this ratio depends on the prices of services and hence we have the price adjustment term $(A/B+c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}} = (p_k)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$. If the prices of entertainment services change, this generates the two standard, and conflicting, effects on the demand for the subsistence good, namely the substitution and income effects. The price adjustment term represents the net of these two effects. In particular, suppose $\widehat{\rho} > 0$. Then when entertainment services are cheaper, reflected in a smaller p_k, spending on the subsistence good will be reduced, because in this case the substitution effect dominates the income effect.

The aggregate supply of the subsistence good – the right hand side term – increases with k. 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.[33] 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 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 (24) can be re-arranged into

$$\mu^{\frac{1}{1-\widehat{\rho}}} H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}} = (A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}(k-k_0), \tag{25}$$

As argued above, the left hand side of (25) 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 (25) linearly increases from 0 to some positive number. Both sides are depicted in Figure 3. This argument leads to the following proposition:

Proposition 1. *A unique equilibrium exists, in which $k \in (k_0, 1)$, and is given by (25).*

[32] 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 spending on the former good is μ times that on the latter good.

[33] 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 $k = 1$.

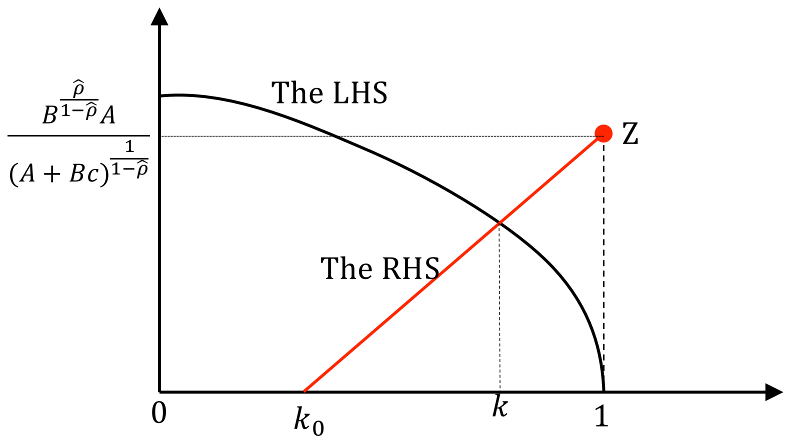

Figure 3: The Existence and Uniqueness of Equilibrium

5.1. Technological Changes that Expand the Limit of IRS

Here we consider the comparative statics with respect to B, the IRS limit.[34] We consider first how an increase in B affects the occupational choice of the agents, captured by k, and then consider its effect on the income distribution. The equilibrium k is determined by equation (24), which is derived from the market clearing condition associated with the subsistence good. From this equation, we can see that an increase in B generates two effects that impact k. First, the term on the right hand side of (24), which represents the aggregate supply of the subsistence good, goes down because $k_0 = Bc/(A + Bc)$ increases with B. Intuitively, a larger B means that more labor is required as input into the production of entertainment services. Hence, given the total supply of labor (i.e., k), fewer workers are employed to produce the subsistence good and less of the good is produced. As result, given the demand for the subsistence good, a rise in B implies that more agents will supply labor in order to meet the demand. That is, the supply-side effect alone drives k up.

The second effect, from the left hand side of (24) (which represents the aggregate demand for the subsistence good), is that the price adjustment term, $(A/B + c)^{\frac{\hat{\rho}}{1-\hat{\rho}}}$, changes with B. If $\hat{\rho} < 0$, this term increases with B, and so does the aggregate demand for the subsistence good. Intuitively, when the quantity of each variety increases, entertainment services in general become relatively cheaper. This increases the demand for the subsistence good if $\hat{\rho} < 0$ because in this case the income effect dominates the substitution effect. A greater demand for the subsistence good induces more agents to provide labor – that is, it also pushes k up. Therefore, if $\hat{\rho} < 0$, the effect on the

[34]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 the change we are considering. Later we consider the comparative statics for the case in which the capacity constraint is binding for some share of entertainers.

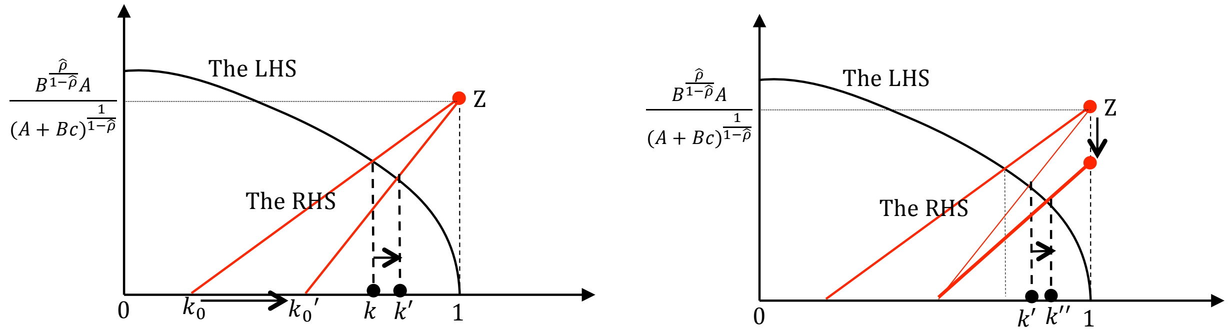

Figure 4: The effect of an increase in B on k. The left panel: an increase in B moves k_0 to k', which increases k to k'. The right panel: if point Z moves down, then k is shifts further to k''

demand side moves k in the same direction as that on the supply side, namely upwards.

However, if $\widehat{\rho} > 0$, the price adjustment term $(A/B + c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$ decreases with B, and so does the demand for the subsistence good, due to the fact that the substitution effect dominates the income effect in this case ($\widehat{\rho} > 0$). In this case, the demand-side effect alone drives k down, in the opposite direction to the supply-side effect. The trade-off between them determines its net movement – up or down. As the demand-side effect vanishes at $\widehat{\rho} = 0$, where the substitution effect is exactly 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. One such condition is given in the following proposition.

Proposition 2. *If*

$$\widehat{\rho} \leq \frac{Bc}{A + Bc}, \tag{26}$$

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. ∎

To explain the intuition for condition (26), we turn to equation (25), 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, from k to k'. Second, the uppermost part of the line, Z, may shift up or down. If Z moves down then k shifts further to the right (to the position k''), as is illustrated in the right panel of the Figure.

In addition, the height of Z is $AB^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}/(A+Bc)^{\frac{1}{1-\widehat{\rho}}}$. Thus, Z moves down with an increase in B if $d\left[AB^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}/(A + Bc)^{\frac{1}{1-\widehat{\rho}}}\right]/dB \leq 0$, which is equivalent to (26). This condition is assumed to hold in the rest of this subsection.

According to Proposition 2, if $\widehat{\rho}$ is small then an increase in B leads the marginal entertainer to be driven out of the entertainment occupation and to thus become a labor provider.

Note that in our model economy, agent i's net gain from becoming a professional relative to providing labor is $(p_i - c) \times B - A$. If an increase in B pushes the agent out of the profession – that is, if this net gain becomes negative – then this must be due to a decrease in p_i – that is, the price of her variety is reduced due to heightened competition. This is a difference with Melitz (2003) where the price of each variety does not respond to changes in the number, or prices, of competing varieties. Indeed, in our setting, in which we consider IRSL rather than IRS, all the varieties get cheaper with an increase in B, as stated in the following lemma:

Lemma 1. *For $i > k$, $dp_i/dB < 0$.*

Proof. From the discussion sitting between equations (17) and (18), we know that $p_i = p_k \times h_i^\rho / h_k^\rho$ and $p_k = A/B + c$. Thus $d\log p_i/dB = d\log p_k/dB - d\log h_k^\rho/dB < -d\log h_k^\rho/dB = -\left(\rho h_k'/h_k \times dk/dB\right) < 0$, as $h_k' > 0$ and $dk/dB > 0$ by Proposition 2. ∎

Having examined the effect of an increase in B on occupation 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, A. These agents therefore lose. This result is stated as the following proposition:

Proposition 3. *There exists $\widehat{k} > k$ such that $dm_i/dB < 0$ for $i \in (k, \widehat{k})$ – 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 states:

Proposition 4. *For $i > k$, $\frac{d\log m_i}{dB}$ strictly increases with m_i – namely the rate of change in the income of entertainers is positively correlated with their present income.*

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

According to this proposition, the higher the current income of an entertainer, the more the entertainer gains (or the less she loses) following an increase in the limit of IRS. This leads to growth in income inequality within the entertainment occupation. The intuition for the proposition is as follows. An increase in B impacts the entertainers' revenues in two ways (while also increasing their cost, Bc). First, a positive effect: a rise in B expands 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 lower prices of entertainment services which reduces revenues (all else equal). Whereas all entertainers face the same degree of competition, an entertainer who has relatively more human capital – and thus earns relatively more – receives a greater gain from the enlargement in capacity because she provides a better quality of service and is therefore able to charge a higher price for her variety. 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.

We note that a corollary of Proposition 4 is that if $i > j > k$ and thus $m_i > m_j$, then $d \log m_i/dB > d \log m_j/dB$. That is, the log wage gap between agents i and j increases with B. If we let i and j be an agent respectively at the 90th and 10th (or 50th) percentile of the income distribution, then a corollary of Proposition 4 is that $\log w_{90\%} - \log w_{10\%}$ (or $\log w_{90\%} - \log w_{50\%}$) grows due to an increase in the scope of operation for the occupation. This corollary provides the theoretical foundation for our earlier regression specification given by equation (3).

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

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

We can then state the following:

Lemma 2. *Assume that $\Omega(\rho) \cdot A/(A + Bc) < 1$ and $\widehat{\rho} \geq 0$. Then $dm_i/dB > 0$, namely agent i's income rises with an increase in the limit of IRS as long as*

$$\frac{h_i}{h_k} > \left(\frac{1}{1 - \Omega(\rho) \cdot A/(A + Bc)} \right)^{\frac{1}{\rho}}. \tag{27}$$

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

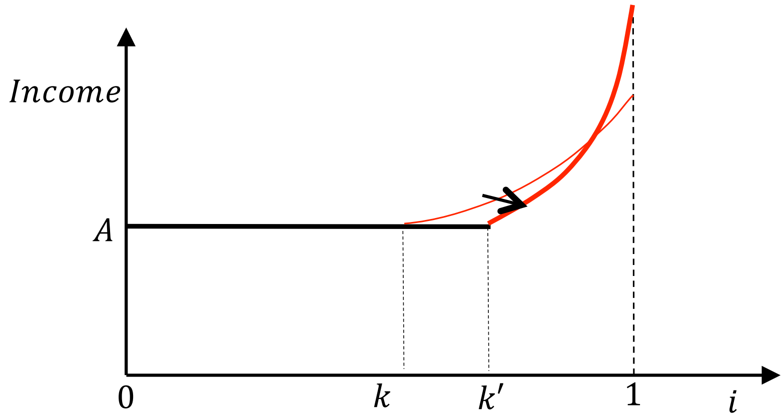

Figure 5: An increase in B squeezes the lower-end entertainers out, and raises income inequality within the entertainment occupation.

Condition (27), 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 $h(i)$). We therefore present an approach, dispensing with k, to obtain 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 3. *Assume $h_1 > 1$. If for some ζ, $h_1 \geq \zeta \cdot h(f(k_0, D \cdot \zeta^{\frac{\rho}{1-\widehat{\rho}}}))$, then $h_1 > \zeta \cdot h_k$.*

Proof. We relegate the proof to Appendix A.5. ∎

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. *Assume that $\Omega(\rho) \cdot A/(A + Bc) < 1$ and $\widehat{\rho} \geq 0$. If $h_1 > 1$ and $h_1 \geq \xi \cdot h(f(k_0, D \cdot \xi^{\frac{\rho}{1-\widehat{\rho}}}))$, then $dm_1/dB > 0$.*

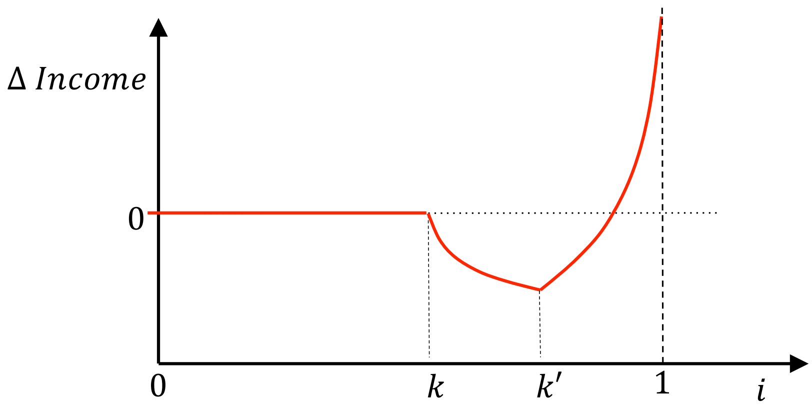

Figure 6: Income growth due to an expansion in B.

Thus, if agents have enough human capital then they reap a net gain from an increase in the limit of IRS. Note that the condition in this proposition focuses on only two points of the function $h(i)$, namely at $i = 1$ and $i = f(k_0, D \cdot \xi^{\frac{\rho}{1-\rho}})$, and hence it can be satisfied by any distribution of human capital in which $h(1)$ is sufficiently large. 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 leads to a change in the income distribution depicted in Figure 5. This results in a U-shaped change in income across agents, as illustrated in Figure 6.

5.2. An Increase in the Productivity of Unskilled Labor

We now consider the comparative statics with respect to A, the productivity of (unskilled) labor. As in the case of an expansion in B, 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 although an increase in labor productivity increases the productivity of entertainment services since fewer workers are needed to produce the same amount of entertainment, it meanwhile increases the wage of labor and, on net, the marginal (labor) cost of producing entertainment services, $w \times c/A$, stays constant at c, since $w = A$. In this sense we say that an increase in A is biased toward (unskilled) labor. It seems at first glance that 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. This general equilibrium effect, we will show, dominates the direct effect for the impact on both occupation choice and the income distribution.

To consider the impact on occupation choice, we return to equation (24), 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 the 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 (24)), the movement depends on the price adjustment factor, $(A/B+c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$. This factor decreases with A if $\widehat{\rho} \leq 0$. Intuitively, a larger A induces a greater supply of the subsistence good, which therefore makes entertainment services relatively more expensive – as $p_k = A/B + c$ increases with A. This change induces a substitution effect and an income effect with respect to the demand for the subsistence good. If $\widehat{\rho} \leq 0$, the latter dominates the former, on net reducing the demand for the subsistence good. It follows that the force on the demand side, similar to that on the supply side, drives k down. Hence, if $\widehat{\rho} \leq 0$, $dk/dA < 0$.

However, the price adjustment factor, $(A/B + c)^{\frac{\widehat{\rho}}{1-\widehat{\rho}}}$ increases with A if $\widehat{\rho} > 0$, in which case the substitution effect dominates the income effect and hence a rise in the relative price of entertainment service increases demand for the subsistence good. This effect on the demand side alone, then, induces k to go up. The effect, however, vanishes if $\widehat{\rho} = 0$ in which case the substitution effect is exactly offset by the income effect. By an argument of continuity, we expect that this demand-side effect will be dominated by the negative effect on the supply side when $\widehat{\rho}$ is small. Hence,

Proposition 6. *If $\widehat{\rho} \leq \frac{Bc}{A+Bc}$ – i.e., (26) holds – then $dk/dA < 0$.*

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

To provide intuition for this condition, we again highlight equation (25), the two sides of which are depicted in Figure 7. The LHS, represented by the curve, is independent of A. Thus, the curve in Figure 7 does not shift with an increase in A. As for the RHS, an increase in A shifts the straight line in Figure 7 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 Z moves upward, then k falls further to k'', as illustrated by the right panel of the Figure.

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

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

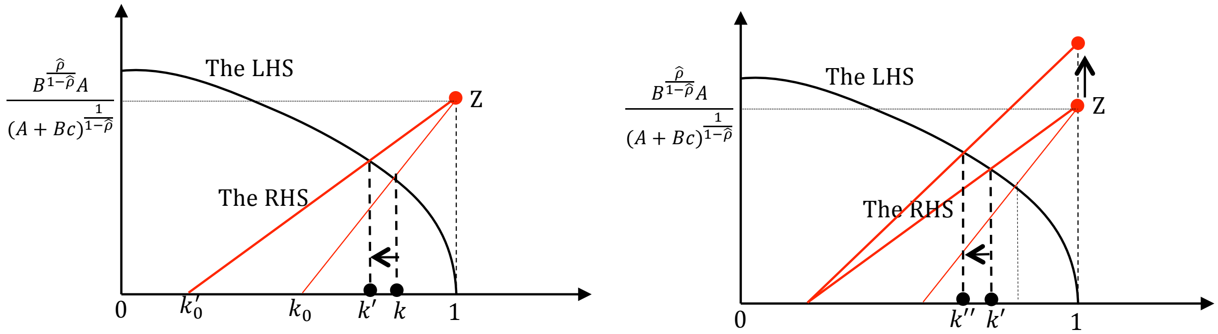

Figure 7: The effect of an increase in A on k. The left panel: an increase in A moves k_0 to the left, which decreases k to k'. The right panel: if Z moves upward, then k falls further to k''

which is equivalent to (26).

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 with respect to the impact of an increase in A on occupation choice.

Having examined the effect of an increase in A on occupation 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 according to 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, $\frac{dm_i}{dA}$ 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 becoming richer, the agents spend more on entertainment services. As an entertainer, agent i acquires a fraction h_i^ρ / H_k^ρ of 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 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

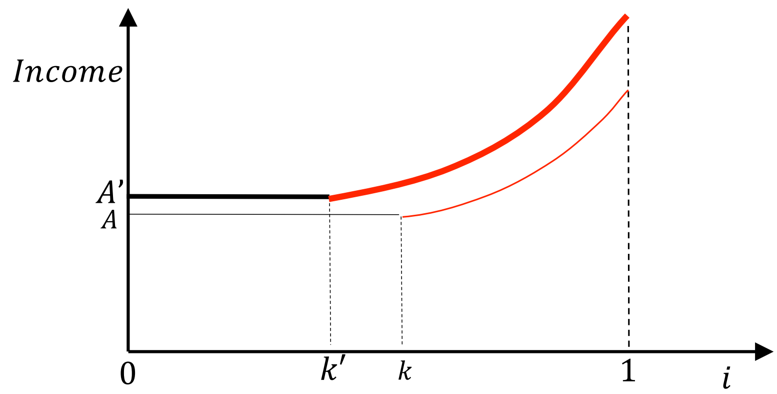

Figure 8: An increase in A raises all agents' incomes while also increasing income inequality.

any of the labor providers. This is a direct implication of the change in occupation 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 8.

5.3. Discussion

When the Capacity Constraint Is Non-Binding for Some Entertainers

Thus far we have considered the case in which the capacity constraint, $D(p; h) \leq B$, is binding for all 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 (9), 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 be binding for all entertainers. Since the entertainers' problem is given by (11), 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 above c/ρ. This condition, with p_k given by (16) with $i = k$, formally is:

$$\Big(\frac{Mf(P,\mu)}{B}\Big)^{1-\rho} h_k^\rho > \frac{c}{\rho}. \tag{28}$$

Hence if this condition holds, then the relevant equilibrium is the case in which the capacity constraint is binding for all the entertainers, and 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 $i^* \in (k, 1)$ such that it is non-binding for $i < i^*$ and binding for $i > i^*$. In particular, it is non-binding for the marginal entertainer, k. In this case, the propositions derived above all hold true qualitatively. Formally:

1. 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.
2. Proposition 2 still holds, and therefore so does Proposition 3 which is a consequence of 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 condition less strict than (26). That is because the marginal entertainer, now with a non-binding capacity constraint with a present value of B, gains nothing from an increase in B, whereas in the case of his capacity constraint being binding, he obtains a positive effect due to the loosening of the constraint. In the absence of this offsetting positive effect, the marginal entertainer is pushed out of the profession by an even stronger force.
3. Proposition 4 still holds, and is formalized in the following proposition.

Proposition 8. *Suppose there exists $i^* \in (k, 1)$ such that the capacity constraint is non-binding for $i < i^*$ and strictly binding for $i > i^*$. Then for $i > k$, $\frac{d\log m_i}{dB}$ increases with m_i and this increase is strict for $i > i^*$.*

Proof. For entertainers $i < i^*$, their capacity constraint is non-binding and the optimal price for them is thus $p_i = c/\rho$. From equation (9) and (19), $m_i = \varpi(B) \times h_i^{\rho/(1-\rho)}$ for some function of B, $\varpi(B)$. Thus $\frac{d\log m_i}{dB} = \frac{d\log \varpi(B)}{dB}$ is independent of m_i or weakly increasing with it. For entertainers $i > i^*$, their capacity constraint is binding. Thus equation (16) holds. Following the discussion ensuing this equation we find that $p_i = p_{i^*} \times h_i^\rho / h_{i^*}^\rho$ and hence $m_i = (p_i - c)B = p_{i^*} B \times h_i^\rho / h_{i^*}^\rho - Bc$. As the capacity constraint just starts binding at i^*, we know that $p_{i^*} = c/\rho$ and independent of B. Furthermore, obviously $di^*/dB > 0$, that is a larger B reduces the number of the agents to whom the capacity constraint is binding. Then following the proof of Propositions 4 we let $\widetilde{m}_i := m_i + Bc = p_{i^*} B \times h_i^\rho / h_{i^*}^\rho$. And we have $\frac{d \log \widetilde{m}_i}{dB} = \frac{1}{B} - \rho \frac{h'_{i^*}}{h_{i^*}} \frac{di^*}{dB}$ and that $\left[\frac{d \log m_i}{dB}\right]'_{m_i} > 0 \Leftrightarrow -\frac{d \log \widetilde{m}_i}{dB} \times B + 1 > 0 \Leftrightarrow -\left[\frac{1}{B} - \rho \frac{h'_{i^*}}{h_{i^*}} \frac{di^*}{dB}\right] \times B + 1 > 0 \Leftrightarrow \rho \frac{h'_{i^*}}{h_{i^*}} \frac{di^*}{dB} \times B > 0$, which holds true as we saw $\frac{di^*}{dB} > 0$. ∎

This proposition, again, motivates our earlier regression specification (3).

4. Proposition 5 hold qualitatively; that is, if the human capital of an entertainer is large enough, she will gain on net from a greater scope of operation. However, the exact conditions for this proposition will change since M, P and k will be ruled by a different profile of equilibrium conditions. Intuitively, both Propositions 4 and 5 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.
5. 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. The intuition in the Cobb-Douglas case is the following. First, recall equation (24), which determines equilibrium k via market clearing of the subsistence good in units of the revenue of the marginal entertainer. Given k, an increase in A increases the supply of the good, while the aggregate demand, measured in units of the marginal entertainer's revenue, is unchanged in the the Cobb-Douglas case because both the proportion of aggregate income to the marginal entertainer's income and the fraction of the aggregate income spent on the subsistence good are unchanged in this case. Therefore, an increase in A must reduce the number of agents who supply labor; that is, moves k leftward.
6. 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 she 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 on their scales of operation. 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 $\widetilde{B}$ (this $\widetilde{B}$, for example, denotes the maximum number of patients that a doctor can see):

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

Each agents' utility is given by

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

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? Instead of the formal analysis for this extended model, 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. Vice versa if $\widehat{\rho} < 0$.

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.

Observe that either effect is in the same direction across all the workers in the unaffected occupation. That is, either they all gain, or they all lose, from a change in B to the affected occupation. Furthermore, 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. It follows that if the effect is positive – namely all the workers in the unaffected occupation gain – then the higher earners gain more and hence inequality within the unaffected occupation rises, but if the effect is negative, the inequality goes down. Put differently, the direction of change in

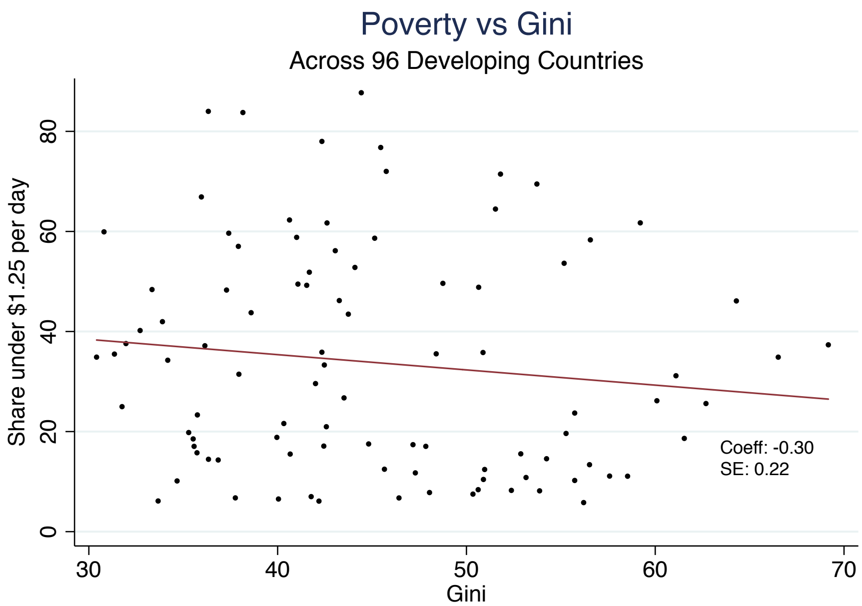

Figure 9: Poverty and Inequality. Source: United Nations

inequality within unaffected occupations due to an increase in the limit of IRS for some occupation is indefinite.

Finally, note that if B is unchanged then there is no “affected occupation”. Thus an increase in A affects both occupations in the same way as explained above.

6. Suggestive Evidence on Type A Technological Progress

In this subsection, we discuss suggestive evidence linking type A technological change to observed long-run structural trends. In the model, the term A represents the productivity of labor and represents the lowest income paid to agents in the economy in equilibrium. Here, 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, as 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 an increase in the share of employment in services occupations, where 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, which are key features of our model. 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.

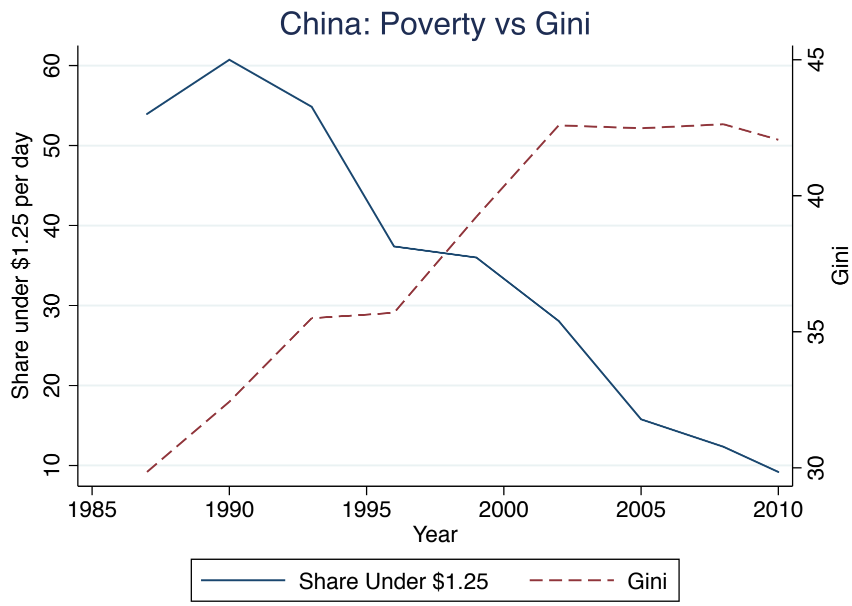

Figure 10: Poverty and Inequality in China. Source: United Nations

In contrast to the most prominent theory of structural change, in our model inequality is driven by shifts in the occupation structure and rising wage earnings, rather than rural-to-urban migration and rising returns to capital. While not ruling out other mechanisms, we show that the empirical facts are jointly consistent with our mechanisms.

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.[35] 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,[36] 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.

[35] 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.

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

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 avoid the potentially confounding effects due to type B technological change.[37] 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.[38]

In addition, whereas the Kuznets curve narrative ascribes rising inequality within developing countries to the gains reaped by capital owners, our channel attributes it to rising wage income. 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)).

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

[38]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)

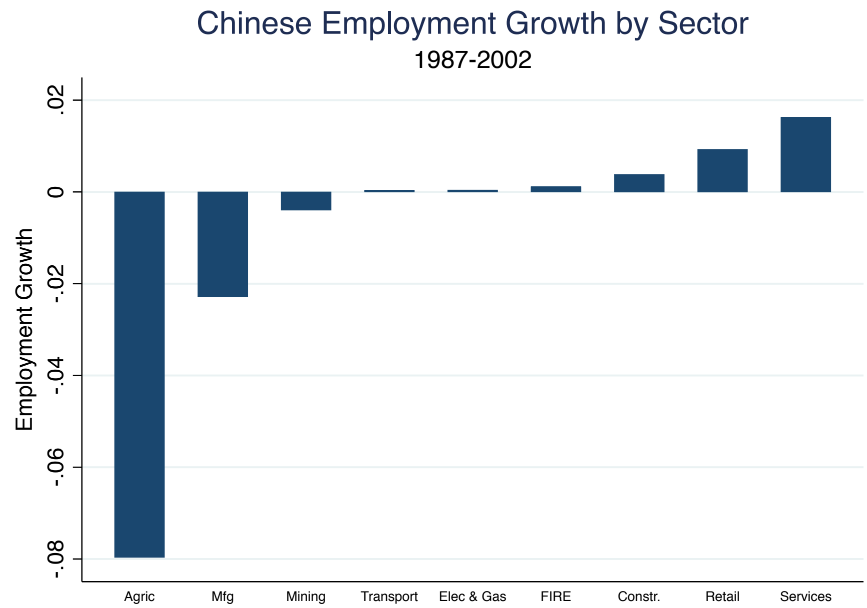

Figure 11: Percentage Point Change in the Chinese Employment Share. Source: United Nations

7. Concluding Remarks

Technological changes of various types are constantly reshaping economies, generating winners and losers. In this paper we introduced new stylized facts with respect to rising inequality within occupations. We then reconciled these facts within the context of a theoretical model that highlights two new channels through which technological change may increase within-occupation income inequality. In contrast to a standard SBTC model, the way in which tasks are performed within an occupation remains unchanged in both cases, and the income distribution within the occupation increases due to rising competition, or rising incomes, and workforce reallocation.

We conclude by noting that there are clearly many other types of technological changes, and each may have different implications for the economy. Furthermore, there are a range of forces, both technological and otherwise, that have contributed to the rising inequality observed in many countries in recent decades. We believe that the technological forces that we consider here are important in part due to their near ubiquity, as well as the fact that they may be relatively difficult for policy-makers to counter compared to institutional factors such as the extent of unionization or tax policies.

Appendix A. Proofs

Appendix A.1. Proof of Proposition 2

Proof. k is determined by equation (25). Differentiating with respect to B on both sides, we find

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

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

On the RHS we consider two cases depending on the sign of $\widehat{\rho}$. (i) if $\widehat{\rho} \geq 0$, 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 $\widehat{\rho} \leq \frac{Bc}{A+Bc}$, then the RHS is negative and thus $dk/dB > 0$.

(ii) if $\widehat{\rho} < 0$, note that the RHS of the equation that pins down dk/dB (see the second line of the proof above) is equal to $(k-k_0) \times \frac{d(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}}{dB} + (A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}} \times \frac{d(1-k_0)}{dB}$. If $\widehat{\rho} < 0$, then $\frac{-\widehat{\rho}}{1-\widehat{\rho}} > 0$ and hence $\frac{d(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}}{dB} < 0$. Given $k > k_0$, we then have $(k-k_0) \times \frac{d(A/B+c)^{\frac{-\widehat{\rho}}{1-\widehat{\rho}}}}{dB} < 0$. Moreover, with $1-k_0 = \frac{A}{A+Bc}$, obviously $\frac{d(1-k_0)}{dB} < 0$. Therefore, the RHS of (25) 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 (19), $\frac{dm_i}{dB} = h_i^\rho/h_k^\rho \cdot [c-(A+Bc)\cdot\rho\cdot(\log h_k)'\cdot\frac{dk}{dB}]-c$. 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. We go to prove that $\frac{d\log m_i}{dB}$ increases with m_i. Let $\widetilde{m}_i := m_i + Bc$. Then

$$\frac{d\log m_i}{dB} = \frac{d\log \widetilde{m}_i}{dB} \times \frac{\widetilde{m}_i}{m_i} - \frac{c}{m_i}. \tag{A.1}$$

By (19

$$\widetilde{m}_i = (Bc+A)\frac{h_i^\rho}{h_k^\rho}.$$

Thus $\log \widetilde{m}_i = \log(Bc+A) + \rho\log h_i - \rho\log h_k$ and

$$\frac{d\log \widetilde{m}_i}{dB} = \frac{c}{Bc+A} - \rho\frac{h_k'}{h_k}\frac{dk}{dB} \tag{A.2}$$

and is independent of m_i. Hence, from (A.1), $\left[\frac{d\log m_i}{dB}\right]'_{m_i} = \frac{d\log \widetilde{m}_i}{dB} \times \left[\frac{\widetilde{m}_i}{m_i}\right]'_{m_i} - \left[\frac{c}{m_i}\right]'_{m_i} = \frac{d\log \widetilde{m}_i}{dB} \times \frac{-Bc}{m_i^2} + \frac{c}{m_i^2}$. It follows that $\left[\frac{d\log m_i}{dB}\right]'_{m_i} > 0$ if and only if

$$\begin{aligned} \frac{d\log \widetilde{m}_i}{dB} \times \frac{-Bc}{m_i^2} + \frac{c}{m_i^2} &> 0 \Leftrightarrow \\ -\frac{d\log \widetilde{m}_i}{dB} \times B + 1 &> 0, \end{aligned}$$

which, from (A.2), is equivalent to

$$1 > \left[\frac{c}{Bc+A} - \rho \frac{h'_k}{h_k}\frac{dk}{dB}\right] \times B.$$

This inequality, as $h'_k > 0$ and $\frac{dk}{dB} > 0$ (Proposition 2), follows from $1 > \frac{c}{Bc+A} \times B$, which obviously holds true. ∎

Appendix A.4. Proof of Lemma 1

Proof. By (19),

$$\frac{dm_i}{dB} = h_i^\rho / h_k^\rho \cdot [c - (A+Bc)\cdot\rho\cdot(\log h_k)' \cdot \frac{dk}{dB}] - c. \tag{A.3}$$

The identity of the marginal entertainer, k, is determined by equation (25). 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,

$$\frac{dk}{dB} < \frac{Ac/(A+Bc)^2}{1+\rho(\log h_k)'(k-k_0)}. \tag{A.4}$$

By (A.3), $\frac{dm_i}{dB} > 0$ if

$$h_i^\rho / h_k^\rho \cdot [c - (A+Bc)\cdot\rho\cdot(\log h_k)' \cdot \frac{dk}{dB}] > c. \tag{A.5}$$

With an upper bound of $\frac{dk}{dB}$ given by (A.4), this inequality follows from: $h_i^\rho / h_k^\rho \cdot [c - (A+Bc)\cdot\rho\,\cdot$

$(\log h_k)' \cdot \frac{Ac/(A+Bc)^2}{1+\rho(\log h_k)'(k-k_0)}] > c \Leftrightarrow$

$$h_i^\rho / h_k^\rho \cdot [1 - \frac{A}{A+Bc} \cdot \frac{\rho \cdot (\log h_k)'}{1+\rho(\log h_k)'(k-k_0)}] > 1, \tag{A.6}$$

which is equivalent to (27). ∎

Appendix A.5. Proof of Lemma 2

Proof. We prove the lemma in three steps.

Step 1: If $h_1 > 1$, then

$$k - k_0 < D(\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}} (1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}. \tag{A.7}$$

Proof: k is determined by equation (25), or equivalently, $k - k_0 = DH_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}}$. Note that $H_k = \{\int_k^1 h_i^\rho\}^{\frac{1}{\rho}}|_{h_i'>0} < \{\int_k^1 h_1^\rho\}^{\frac{1}{\rho}} = h_1(1-k)^{\frac{1}{\rho}}$. Therefore, $H_k^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} h_k^{\frac{-\rho}{1-\widehat{\rho}}} = (\frac{H_k^{\rho-\widehat{\rho}}}{h_k^\rho})^{\frac{1}{1-\widehat{\rho}}} < (\frac{h_1^{\rho-\widehat{\rho}}(1-k)^{\frac{\rho-\widehat{\rho}}{\rho}}}{h_k^\rho})^{\frac{1}{1-\widehat{\rho}}} = h_1^{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}}} / h_k^{\frac{\rho}{1-\widehat{\rho}}} \cdot (1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}|_{\frac{\rho-\widehat{\rho}}{1-\widehat{\rho}} \le \frac{\rho}{1-\widehat{\rho}} \text{ and } h_1>1} < h_1^{\frac{\rho}{1-\widehat{\rho}}} / h_k^{\frac{\rho}{1-\widehat{\rho}}} \cdot (1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}}$, which implies (A.7).

Step 2:

$$k < f(k_0, D \cdot (\frac{h_1}{h_k})^{\frac{\rho}{1-\widehat{\rho}}}). \tag{A.8}$$

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.7) 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 $\tau \le k$, then the LHS of the inequality is negative, while the RHS is positive – and thus cannot be strictly smaller than the LHS – because $1-\tau \ge 1-k$, which implies $(1-\tau)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}} - (1-k)^{\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})}} \ge 0$ (as $\frac{\rho-\widehat{\rho}}{\rho(1-\widehat{\rho})} > 0$). Q.E.D.

Step 3: We prove the Lemma by showing that $\zeta \ge h_1/h_k$ leads to a contradiction. Clearly, $f(k_0, y)$ increases with y, and therefore if $\zeta \ge h_1/h_k$, 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.8) 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

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

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 (25). Differentiate with respect to A on both sides, and we find

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

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

On its RHS, we consider two cases depending on the sign of $\hat{\rho}$. (i) if $\hat{\rho} \geq 0$, $d(A/B+c)\frac{-\hat{\rho}}{1-\hat{\rho}}/dA < 0$ and $k-1 < 0$. Therefore, if

$d[(1-k_0)(A/B+c)\frac{-\hat{\rho}}{1-\hat{\rho}}]/dA \geq 0$,

which (as $k_0 = \frac{Bc}{A+Bc}$) is equivalent to $\hat{\rho} \leq \frac{Bc}{A+Bc}$, then the RHS is positive and

thus $dk/dA < 0$.

(ii) if $\hat{\rho} < 0$, note that the RHS of the equation that pins down dk/dB (probably we shall number of the equation) is equal to $(k-k_0) \times \frac{d(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}}{dA} + (A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}} \times \frac{d(1-k_0)}{dA}$. If $\hat{\rho} < 0$, then $\frac{-\hat{\rho}}{1-\hat{\rho}} > 0$ and hence $\frac{d(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}}{dA} > 0$. Given $k > k_0$, we then have $(k-k_0) \times \frac{d(A/B+c)^{\frac{-\hat{\rho}}{1-\hat{\rho}}}}{dA} > 0$. Moreover, with $k_0 = \frac{Bc}{A+Bc}$, obviously $\frac{d(1-k_0)}{dA} = -\frac{dk_0}{dA} > 0$. Therefore, the RHS of (25) is positive and thus $dk/dA < 0$. ∎

Appendix A.7. Proof of Proposition 7

Proof. By (19), $\frac{dm_i}{dA} = \frac{h_i^\rho}{h_k^\rho} + (Bc+A)(-\rho)\frac{h_i^\rho}{h_k^{\rho+1}} \cdot h_k' \cdot \frac{dk}{dA} = \frac{h_i^\rho}{h_k^\rho} \cdot [1 + (Bc+A)(\log h_k)' \cdot (-\rho\frac{dk}{dA})]|_{-\rho\frac{dk}{dA}>0 \text{ (by Prop. 5)}} > \frac{h_i^\rho}{h_k^\rho} \geq 1$. Moreover, by (19), $\frac{h_i^\rho}{h_k^\rho} = \frac{m_i+Bc}{A+Bc}$. 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. Internet Exposure Measure

Our measure of internet exposure, B_{it}^{Int}, is constructed as in (2). 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 (2).

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