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EARNINGS INEQUALITY AND THE BUSINESS CYCLE

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ABSTRACT

Economists have long viewed recessions as contributing to increasing inequality. However, this conclusion is largely based on data from a period in which inequality was increasing over time. This paper examines the connection between long-run trends and cyclical variation in earnings inequality. We develop a model in which cyclical and trend inequality are related, and find that in our model, recessions tend to amplify long-run trends, i.e. they involve more rapidly increasing inequality more when long-run inequality is increasing, and more rapidly decreasing inequality when long-run inequality is decreasing. In support of this prediction, we present evidence that during the first half of the 20th Century when earnings inequality was generally declining, earnings disparities indeed appeared to fall more rapidly in downturns, at least among workers at the top of the earnings distribution.

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Introduction

In recent years, economists have resurrected the question of how earnings inequality evolves over the business cycle. While this question was raised long ago by economists concerned with the impact of downturns on the poor, the renewed interest in this question comes instead from economists concerned with whether earnings are more volatile in recessions, which would imply greater earnings dispersion in recessions. Conventional wisdom based on the last 40 years suggests both wage and income inequality rise during recessions. However, it is also well-known that this same period was characterized by a dramatic secular increase in earnings inequality. Should we be concerned that the evidence for increasing inequality during recessions comes from a period in which inequality was generally increasing? Are changes in inequality over the cycle related to whatever forces are driving long-run trends in the earnings distribution?

This paper tackles these questions by introducing cyclical fluctuations into a model of secular changes in earnings inequality. We find that recessions in our model serve to amplify long-run trends in inequality, rather than necessarily contributing to greater inequality. That is, recessions contribute to more rapid growth in earnings inequality in periods of rising inequality, but they accelerate the fall in earnings disparities in periods of declining inequality. Focusing on a period of rising inequality may therefore overstate the extent to which recessions involve increased earnings inequality.

To assess the plausibility of our assertion that business cycles need not have a uniform impact on the distribution of earnings, we look back in history to a period in which inequality was secularly decreasing, namely the period from the late 1920s to the early 1950s. According to our model, we should observe that economic downturns during this period, notably the Depression of 1929-1932 and the subsequent recession of 1937, were associated with a more rapid decline in earnings dispersion among employed workers, specifically among workers at the top of the wage distribution. We assemble various pieces of evidence that suggest inequality among employed workers at the top of the earnings distribution indeed decreased more rapidly during these downturns. This stands in sharp contrast with the effect of downturns that both preceded and proceeded this period, when inequality was generally increasing. Of course, given the limitations on the data and the exceptional nature of the Great Depression as a historical episode, these patterns are at best suggestive rather than conclusive proof of our assertion. Moreover, both our model and our empirical analysis ignore unemployment and other considerations that systematically contribute to higher inequality in recessions. Nevertheless, our results suggest long-run trends in earnings inequality may be relevant for how cyclical fluctuations ultimately effect the distribution of earnings.

Interestingly, our findings raise questions about a growing strand of literature which argues that countercyclical earnings volatility, and hence countercyclical earnings inequality, can help to resolve some key macroeconomic puzzles. For example, Mankiw (1986), Constantinides and Duffie (1996), Heaton and Lucas (1996), and Storesletten, Telmer, and Yaron (2003) argue that if incomes are more volatile in recessions, equities whose dividends are correlated with aggregate income would command large premia even among moderately risk-averse agents, since the return on equity is low precisely when income risk is greatest. Thus, a strong countercyclical pattern in inequality can potentially explain the puzzlingly high equity premium in the U.S. From a different angle, Imrohoroglu (1989), Storesletten, Telmer, and Yaron (2001), and Krebs (2003) argue that if earnings are more volatile during recessions, consumption risk over the cycle would be larger than the volatility of per-capita consumption, so cycles will be more costly than the puzzlingly low cost computed by Lucas (1987). Since our findings suggest that recent data may overstate the contribution of recessions to inequality, claims regarding the quantitative success of these theories may need to be revisited.

The paper is organized as follows. Section 1 develops the model and our theoretical results. Section 2 provides empirical support for the prediction of our model. Section 3 concludes.

1. A Model of Earnings Inequality

We begin by developing a model which we can use to explore the connection between trend inequality and cyclical variation in inequality. We model trend inequality as being driven by technological change, in line with recent work that identifies technical change as a key factor behind the rising inequality of the last few decades. More precisely, we model an economy that undergoes waves of drastic technological innovation, i.e. every so often a new mode of production becomes available. This new mode is fundamentally incompatible with previous technologies and renders any knowledge associated with them obsolete. Examples of such innovations include the electrification and mechanization of production in the early 20th century and computerization in the late 20th century. The reason such technological changes can affect the distribution of earnings is that agents typically differ in the rate at which they incorporate the new technology. As a result, when a technology first arrives, those who are quick to absorb it will increase their earnings and drift apart from their slower counterparts. Eventually, laggards will catch up as the new technology becomes diffuse, and earnings disparities decline until the next technology arrives. Over the life span of each new technology, then, inequality will first rise and then fall, much as Kuznets (1955) conjectured should be the natural course for a developing economy. Our model is thus similar to Galor and Tsiddon (1997), Greenwood and Yorukoglu

(1997), and Caselli (1999), who also argue that technical change should first raise inequality and then lower it. However, our modelling approach makes the introduction of cyclical fluctuations easier.

For expositional purposes, we only track the life span of a single technology. That is, assuming a new technology arrives at date $t = 0$, we solve for the outcome that would prevail at any date $t > 0$ assuming this technology is still in use. Implicitly, we have in mind that new technologies arrive stochastically at a constant rate, and that our analysis describes the evolution of the economy conditional on no new technology having arrived. When a new technology does arrive, our assumption that it renders all previous knowledge obsolete implies we can reset the clock to $t = 0$ and restart the process.

We assume labor is the only factor of production and is supplied by a continuum of workers. The productivity of each worker depends on how adept he is in the new technology. Formally, let $s_{it} \in [0, \infty)$ denote worker i's skill level at date t. Heuristically, s_{it} can be viewed as the number of tasks worker i can perform using the new technology. Alternatively, s_{it} could reflect how intensively worker i's job at date t makes use of the new technology; a higher s_{it} implies the worker makes greater use of the new technology, e.g. he starts to work with an electric motor or a computer, either on his current job or by moving to a new job that makes use of such technologies. A worker's productivity depends on his s, in a way to be made precise below.

All individuals start out with the same skill level at date $t = 0$ when the technology is first introduced, i.e. $s_{i0} = s_0$ for all i. However, they can become more adept at using this technology over time. We model this process as in Ben-Porath (1967). That is, each individual has a unit of time each instant that he can allocate to either production or becoming more proficient in the new technology. Let $n_{it} \in [0, 1]$ denote the fraction of time that individual i spends on becoming proficient, i.e. the time he spends learning new tasks or searching for a job that is more intensive in the new technology. The remaining $1 - n_{it}$ is allocated to working. Worker i's output at date t is given by

$$y_{it} = z_t s_{it} (1 - n_{it}) \tag{1.1}$$

where z_t denotes the productivity of the underlying technology. Thus, the more proficient a worker is in the new technology, as reflected by a higher s_{it}, the more productive he will be. For now, we assume z_t is constant over time, i.e. $z_t = Z$ for all t, so we can study secular paths of inequality. In a more general framework each new invention would have been associated with a higher value for Z. However, given that we only track a single technology how Z varies across technologies is irrelevant . There is free entry in using technology (1.1), so workers earn their marginal product in equilibrium. That is, individual i will earn a wage of $w_{it} = Zs_{it}$ per unit of labor, for an income $y_{it} = Zs_{it}(1 - n_{it})$.

Time spent acquiring additional skills contributes to s_{it} according to the technology

$$\dot{s}_{it} = a_i (s_{it} n_{it})^b \tag{1.2}$$

where $a_i > 0$ measures the speed at which individual i learns new skills, and $b \in (0, 1)$ is a constant common to all individuals. The more time the worker devotes to acquiring skills, the more quickly his s_{it} will rise, albeit at a diminishing rate. The rate at which an individual becomes skilled also depends on how many skills he already knows, i.e. past familiarity with the technology aids in accumulating further skills.

Two features of the above technology are essential for our results. First, individuals differ in their speed of learning a_i, i.e. some individuals are inherently quicker to adapt to the new technology. This will drive the dynamics of inequality in earnings across workers. Second, accumulating new skills requires time away from production, so the opportunity cost of learning is the value of producing output. This feature will be especially important when we introduce cyclical fluctuations. The fact that it is workers and not employers who adapt to the new technology is not in itself essential. Of course, in our model there is no incentive for employers to raise their workers' productivity, so only workers would ever undertake such investments.[1] But as Acemoglu and Pischke (1999) note, there are various labor market frictions we could introduce that would allow employers to benefit from having a more productive worker, in which case employers would have incentive to raise the productivity of their workers. As long as firms invest in upgrading the skill of different workers at different rates and the opportunity cost of such investments involves foregone production, our intuition should still go through.

So far, our model is identical to Ben-Porath (1967). However, we introduce one key modification, namely that s_{it} is bounded above by some finite $\overline{s}$. Formally, we replace (1.2) with

$$\dot{s} = \begin{cases} a(sn)^b & \text{if } s < \overline{s} \\ 0 & \text{if } s = \overline{s} \end{cases} \tag{1.3}$$

This assumption implies there is only so much one can get out of a technology; in the long run, sustained growth requires the advent of new technologies. For our purposes, the relevant feature of this assumption is that it introduces diminishing returns to skill, i.e. the return to learning additional skills beyond $\overline{s}$ drops to zero. More moderate degrees of diminishing returns

[1] For a more in depth discussion of who would undertake investment in general skills, see Becker (1975).

should similarly lead quicker workers to eventually slow down and allow their slower colleagues to catch up, and this is the feature we require of our model.[2]

If individuals are risk-neutral and share a common discount rate ρ, each will choose to maximize the present discounted value of his income. Thus, the worker's problem is given by

$$\max_{n_t} \int_0^\infty Zs_t\,(1-n_t)\,e^{-\rho t}dt \tag{1.4}$$

$$\begin{aligned} \text{subject to}\quad & 1.\;\; 0 \le n_t \le 1 \\ & 2.\;\; \dot{s} = \begin{cases} a\,(sn)^b & \text{if } s < \overline{s} \\ 0 & \text{if } s = \overline{s} \end{cases} \\ & 3.\; \text{Initial condition } s_0 \end{aligned}$$

To solve (1.4), note that when $s_t = \overline{s}$, there is no point to learning, so it is optimal to set $n_t = 0$. An individual will earn a constant flow $Z\overline{s}$, which discounted at rate ρ implies that the present discounted utility of an agent for whom $s = \overline{s}$ and who solves (1.4) is given by

$$V(\overline{s}) = \frac{Z\overline{s}}{\rho} \tag{1.5}$$

For $s < \overline{s}$, we apply dynamic programming to solve the worker's maximization problem. The present discounted utility $V(s)$ of an optimizing agent with a current level of skills s is governed by the asset equation

$$\rho V(s) = \max_n \left\{ Zs\,(1-n) + V'(s)\,a\,(sn)^b \right\}$$

Setting aside momentarily the constraint that $0 \le n_t \le 1$, the first-order condition for the above maximization is given by

$$sn = \left(\frac{abV'(s)}{Z} \right)^{\frac{1}{1-b}}$$

This optimum necessarily satisfies the condition that $n_t \ge 0$. As long as s is sufficiently large, one can show that it will also be true that $n_t \le 1$. We will henceforth assume that s_0 is sufficiently large to insure an interior optimum. Substituting back into the asset equation yields a non-linear differential equation

$$\rho V(s) = Zs + m\left(V'(s)\right)^{\frac{1}{1-b}} \tag{1.6}$$

[2] With a uniform bound $\overline{s}$, all workers earn the same wage asymptotically. Our results would go through if we assumed each individual has his own ceiling $\overline{s}_i$, as long as we do it in such a way that those who are quicker to learn reach their ceilings first. In that case, earnings inequality would still fall eventually, but the distribution of wages would converge to a non-degenerate distribution.

where $m = \dfrac{1-b}{b}\left[\dfrac{ab}{Z^b}\right]^{\frac{1}{1-b}}$, with (1.5) as its boundary condition. To solve this differential equation, it will be easier to work with the variable

$$x(s) = V(s) - \frac{Zs}{\rho}$$

The variable $x(s)$ has an economic interpretation: it is the value of the option to learn additional skills when the current skill level is s. This is because if the agent were prevented from learning any additional skills, he would allocate all of his time endowment to work, giving him a discounted utility of $\frac{Zs}{\rho}$. The difference between this and $V(s)$ must then reflect how much the worker would pay to acquire skills beyond s. After some algebraic manipulation, we can rewrite (1.6) as a differential equation in terms of $x(s)$:

$$\frac{dx(s)}{ds} = \left(\frac{\rho x(s)}{m}\right)^{1-b} - \frac{Z}{\rho} \tag{1.7}$$

with a boundary condition $x(\overline{s}) = 0$. As illustrated in the Appendix, we can use the first condition above to express $\dot{s}$ in terms of the value of learning $x(s)$:

$$\dot{s} = a^{\frac{1}{1-b}}\left[\frac{b}{Z}\right]^{\frac{b}{1-b}}\left(\frac{\rho x(s)}{m}\right)^{b} \tag{1.8}$$

The above equation has an appealing interpretation, namely that individuals accumulate more skills when the option to acquire additional skills is more valuable, i.e. when $x(s)$ is larger. In the Appendix, we solve the dynamical system comprised of (1.7) and (1.8) and use it to characterize the optimal path. Our results are summarized in the following Proposition:

Proposition 1: For any $a > 0$, the solution to (1.4) implies

1. The path of the skill level s_t is concave in t.
2. There exists a $T_i < \infty$ such that $s_{it} = \overline{s}$ for all $t \geq T_i$.
3. For any two individuals i and j where $a_i > a_j$, $s_{it} \geq s_{jt}$ for all t, with strict inequality when $s_{it} \in (s_0, \overline{s})$.

Figure 1 depicts these results graphically. Panel (a) illustrates the skill paths for several individuals with different a_i. Each accumulates s at a declining rate over time. To appreciate why, note that one reason for accumulating s is to facilitate accumulating skills in the future (recall that $\dot{s}$ is increasing in s). As agents draw near $\overline{s}$ and anticipate they will soon stop learning, the incentives to accumulate skills are naturally smaller. The more able workers proceed to $\overline{s}$ at a faster average rate than the less able workers. As a result, the distribution of skills across workers, which at $t = 0$ corresponds to a mass point at s_0, fans out as workers accumulate skills at different average rates, then collapses back to a mass point at $\overline{s}$. Panel (b) illustrates the same paths, but with the skill level of each individual depicted relative to the skill level of the least able worker in the population, $\inf_j s_{jt}$. Note that the skill distribution can simultaneously become less disperse at the top and more disperse at the bottom, i.e. the relative skill of those at the top can fall at the same time as the relative skill of those in the middle of the distribution rise. Thus, it may not be possible to generically characterize trends in inequality across all agents in our model, and the only precise statements we can make is about inequality between any two given workers (or any two workers in given percentiles of the relevant distribution). When we later take our model to the data, we will define a period of declining inequality as one in which those at the top of the distribution fall relative to those further down the distribution, as illustrated in Panel (b). As such, we will need to focus on the relative earnings of those at the top of the distribution.

To relate inequality in skills to inequality in earnings, recall that the wage of individual i is equal to $w_{it} = Zs_{it}$. Thus, wages are proportional to skills, and the ratio of the wages of any two individuals is equal to the ratio of their skill levels, so inequality in wages as measured by wage ratios is identical to inequality in skills. From Proposition 1, wage inequality between any two workers will first rise and then fall over the lifetime of a given technology.

The evolution of income inequality is a bit more involved, but follows a roughly similar pattern. At date $t = 0$ when the technology first arrives, all agents earn the same wage Zs_0, but the more able workers spend more time accumulating skills so their income $Zs_0 (1 - n_{i0})$ is lower. Thus, initially the most able workers will earn the lowest incomes. But this pattern is quickly reversed since the incomes of the most able individuals grow faster on average. At that point, the income of those at the top of the distribution will drift apart from the incomes of those further down the distribution, although eventually the latter catch up to them and income inequality will disappear. Abstracting from early transitional dynamics, income inequality is thus parallel to wage inequality: there is a distinct phase in which income disparities increase over time, followed by another distinct phase in which they decrease over time.

To summarize, our model gives rise to secular trends in earnings inequality, first rising and then falling. What we are ultimately interested in, though, is how these trends interact with cyclical fluctuations. To allow for fluctuations, we let z_t vary stochastically over time; in particular, z_t can assume two values, $Z_0 < Z_1$, and switches between the two values at a constant rate μ per unit of time. Our decision to model cyclical fluctuations this way does not imply we view productivity shocks as the unique source of aggregate fluctuations. Instead, our motivation comes from the fact that skill accumulation is driving changes in earnings distribution in our model, and the rate at which individuals accumulate skills depends on the behavior of wages. Since in our model wages depend on productivity, it is only natural to model cyclical fluctuations as productivity shocks. Recessions in our model correspond to periods of low productivity, so wages are procyclical, in line with micro evidence from the past 30 years, e.g. Solon, Barsky, and Parker (1994).

Admittedly, our approach is stylized and abstracts from important considerations such as unemployment distribution. However, such considerations are not important for the particular channel we focus on. Still, it is useful to keep in mind that any predictions that emerge from our model will only be relevant for the distribution of earnings across stably employed workers rather than across the labor force as a whole.

When z_t follows a stochastic process, each worker will act to maximize his expected present discounted value of income, i.e. he will solve

$$\max_{n_t} E_t \left[\int_0^\infty z_t s_t (1 - n_t) e^{-\rho t} dt \right] \tag{1.9}$$

$$\begin{aligned} \text{subject to} \quad & 1.\ \ 0 \le n_t \le 1 \\ & 2.\ \ \dot{s} = \begin{cases} a(sn)^b & \text{if } s < \overline{s} \\ 0 & \text{if } s = \overline{s} \end{cases} \\ & 3.\ z_t \text{ follows a Markov process} \\ & 4.\ \text{Initial conditions } z_0, s_0 \end{aligned}$$

where n_t is measurable with respect to $\{z_\tau\}_{\tau=0}^t$. We first show that along the optimal path, an individual will accumulate skills at a more rapid pace in recessions, i.e. when $z_t = Z_0$. The proof of this, and all remaining propositions, is contained in an Appendix.

Proposition 2: For any realized path $\{z_\tau\}_{\tau \in [0,t)}$, the solution to (1.9) dictates more rapid skill accumulation at date t if aggregate productivity at date t is low, i.e.

$$\dot{s}_{it}|_{z_t = Z_0} \ge \dot{s}_{it}|_{z_t = Z_1}$$

The intuition for this result is based on an intertemporal substitution argument: since the opportunity cost of accumulating skills is lower in recessions, it is better to concentrate skill accumulation in periods of low productivity and rent our labor services for a high price in periods of high productivity.[3] While we have no direct evidence if this is how technology-specific skills

[3]Dellas and Sakellaris (2003) show in a similar model of human capital accumulation that it is optimal to

are accumulated over the cycle, other forms of human capital accumulation do indeed appear to be countercyclical. For example, Betts and McFarland (1995) document significant increases in enrollment in two-year colleges during recessions. Dellas and Sakellaris (2003) look at the fraction of 18-22 year old who report attending college and find it to be strongly countercyclical, especially in two-year colleges and among part-time students. Sepulveda (2002) finds evidence that time spent in formal training, either employer-provided training or off-site training, is likewise negatively correlated with various cyclical indicators.

Since skill accumulation ultimately drives long-run changes in earnings inequality, the fact that recessions encourage more rapid skill accumulation suggests changes in the distribution of earnings would simply be accelerated in recessions. Intuitively, in times of rising inequality, more able workers would presumably have more incentive to take advantage of downturns to accumulate skills, and earnings disparities would grow at a faster rate. Conversely, in times of falling inequality, the less able workers would catch up more quickly to those who have already mastered the new technology. We now confirm these conjectures formally.

Turning first to the case of rising inequality, we proceed by analyzing the special case of the model where there is no upper bound, i.e. $\overline{s} = \infty$. This case can be solved analytically. As the next proposition shows, for $\overline{s} = \infty$ individuals will never cease learning, and as a result less able workers never catch up to their more able colleagues. Thus, the model exhibits rising skill and wage inequality, and one can show that this secular increase in inequality is accelerated in recessions.

Proposition 3: Consider two individuals i and j where $a_i > a_j$, both of whom face the maximization problem (1.4). If $\overline{s} = \infty$, we have

1. For any path $\{z_\tau\}_{\tau \in [0,\infty)}$, the ratio $\dfrac{w_{it}}{w_{jt}}$ is increasing and continuous in t and converges to a finite upper bound

$$\lim_{t \to \infty} \frac{w_{it}}{w_{jt}} = \left(\frac{a_i}{a_j}\right)^{\frac{1}{1-b}} > 1$$

2. Wage inequality grows more rapidly in recessions, i.e. for any path $\{z_\tau\}_{\tau \in [0,t)}$,

$$\frac{d}{dt}\left(\frac{w_{it}}{w_{jt}}\right)\bigg|_{z_t = Z_0} > \frac{d}{dt}\left(\frac{w_{it}}{w_{jt}}\right)\bigg|_{z_t = Z_1} > 0$$

accumulate skills in recessions. The notion that recessions encourage investment in growth-enhacing activities has also been raised by Hall (1991), Cooper and Haltiwanger (1993), and Aghion and Saint Paul (1998). However, none of the above addresses the implications of such results for inequality.

Returning to the case where $\overline{s}$ is finite, one can show that the model exhibits the following 'turnpike' property: for a fixed s_0 and any $\varepsilon > 0$, there exists some finite $\overline{s}$ such that the optimal path $\{n_t\}$ will be within an ε-neighborhood of the optimal path $\{n_t\}$ for the case of $\overline{s} = \infty$, except for some final time period. Thus, one can extend the result a period of rising inequality will be associated with more rapidly increasing inequality during recessions to the case where the level of skills is strictly bounded above, as long as it is sufficiently larger than s_0.[4]

Next, we turn to the case of decreasing inequality. Here, we can establish that recessions will have the opposite effect, i.e. if wage differentials between two individuals are decreasing, they will decrease at an ever faster rate when $z_t = Z_0$:

Proposition 4: Consider two individuals i and j where $a_i > a_j$. Then $s_{it} \geq s_{jt}$ for all t, with strict inequality if $s_0 < s_{it} < \overline{s}$. Moreover, there exists an $\varepsilon > 0$ such that

1. If $|s_{it} - \overline{s}| = \varepsilon$, then $\dfrac{w_{it}}{w_{jt}}$ decreases with t for any continuation path $\{z_s\}_{s=t}^{\infty}$.
2. Wage inequality declines more rapidly in recessions, i.e. for any realized path $\{z_\tau\}_{\tau \in [0,t)}$, if $s_{it} \geq \overline{s} - \varepsilon$, then

$$\frac{d}{dt}\left(\frac{w_{it}}{w_{jt}}\right)\bigg|_{z_t = Z_0} < \frac{d}{dt}\left(\frac{w_{it}}{w_{jt}}\right)\bigg|_{z_t = Z_1} < 0$$

Propositions 3 and 4 are only concerned with wage inequality. Once again, analogous results can be derived for income inequality, subject to certain caveats. Turning first to Proposition 3, the proof in the Appendix implies that the optimal policy when $\overline{s} = \infty$ sets $s_{it} n_{it}$ equal to a constant that depends on the value of z_t. Thus, income is given by

$$y_{it} = z_t s_{it} (1 - n_{it}) = w_{it} - \text{constant}$$

Rising wage inequality must eventually translate into rising income inequality, then, since any differences in the constant term across individuals are eventually swamped by differences in wages across individuals. Likewise, the fact that wages drift apart more rapidly in recessions implies that incomes must drift apart more rapidly as well. However, a recession will *decrease* income dispersion on impact, since high ability workers will shift more of their time to acquiring skills the instant z_t falls. After this initial compression, incomes will diverge at a faster rate so long as z_t is equal to Z_0. Hence, a long enough recession will result in greater income dispersion

[4] For small but finite $\overline{s}$, we can only solve the model numerically. For all the parameter values we experimented with, we confirmed $\dot{(w_{it}/w_{jt})} \mid_{z_t = Z_0} > \dot{(w_{it}/w_{jt})} \mid_{z_t = Z_1} > 0$ within in a neighborhood of $t = 0$.

than if productivity had stayed at its high value throughout. Similarly, we can establish an analog to Proposition 4 in terms of income inequality. Given two individuals, when the more able individual is close to the upper bound $\overline{s}$, the income of the less able individual will converge to the income of the more able individual at a faster rate in recessions. However, on impact a negative shock to z_t will widen income differentials, since the less able households will shift time away from production while the high ability households essentially devote all their time endowment to production and will not vary their labor supply. Still, a long enough recession will result in less income dispersion than if productivity had stayed at its high value throughout.

As a final note, we should emphasize that our model is not intended to capture all of the variation in the distribution of earnings over the cycle. For example, by ignoring unemployment, we abstract from the fact that if low-income households are particularly vulnerable to unemployment, the relative income of poorer households would fall in recessions. As another example, if skilled and unskilled labor were imperfect substitutes, and if skilled workers were more likely to temporarily take on low-skill jobs in recessions, the relative wages of low-skill jobs would also fall in recessions. Both of these would tend to increase inequality in recessions. The point of our analysis, however, is not to fully characterize inequality over the cycle. Rather, it is to point out that fluctuations might interact with the forces that lead to long-run changes in earnings inequality. As a result, even if we were to account for all of the ways in which business cycles affect the distribution of earnings, we should still observe a smaller rise in inequality in recessions when long-run inequality is declining than when it is increasing, even after properly detrending the data. Treating long-run changes in earnings inequality as exogenous trends to be taken out can lead to biased estimate for the effects of recessions on inequality, where the direction of the bias depends on the direction of long-run trend inequality.

2. Evidence on Earnings Inequality over the Cycle

We now turn to empirical evidence in support of our hypothesis. To verify our prediction that downturns are associated with more rapid growth in inequality in periods of rising inequality but with more rapid reductions in inequality in periods of falling inequality, we look back at U.S. history over the past century. This period was marked by an increase in measures of inequality between the early 1900s and the late 1920s, a decline in these same measures from the late 1920s to the early 1950s, and finally a resurgence in earnings inequality starting from the late 1960s persisting until at least the end of the century. These patterns can be reconciled with our model, where changes in inequality are driven by technological upheavals: the rise and fall in inequality in the first half of the century occurred at a time of significant technological change, namely the electrification and mechanization of production, as did the rise in inequality in the second half of the century, namely computerization.

Rather than proceed chronologically, we first focus on the period of declining inequality in the middle of the century and show that the two major downturns of the period were in fact associated with a more rapid decline in earnings inequality. We then contrast these findings with the behavior of the same measures of inequality in periods of rising inequality, both those that predate and postdate this era.

2.1. The Era of Declining Earnings Inequality

We begin with the one episode of declining earnings inequality during the past century. In many respects, it seems reasonable to associate this decline with the tail end of the process of electrification and mechanization of production that dramatically altered the nature of production in the U.S. Although electricity was first introduced at the end of the 19th century, by 1929 it was already widely defused in industry. Schurr *et al* (1990) report that in 1929, nearly 80% of the mechanical drive in manufacturing was already electrified. As such, starting from the late 1920s, there should have been a marked catching-up among remaining production arrangements, and a concomitant compression in the distribution of earnings, at least until the arrival of the next new technology. Indeed, during the 1930s, U.S. producers built significantly on previous technological innovation, in part as firms tried to wring out efficiency gains during these particularly dire times. Bernstein (1987) documents significant technical change even during the depths of the Depression, including further mechanization and electrification of production. Perazich and Field (1940) report that the number of workers devoted to product and process innovation grew at a more rapid rate between 1927 and 1931 than it did during the 1920s. Field (2003) dramatically refers to this period as "the most technologically progressive decade of the century."[5] The fact that long-run inequality was declining during this period suggests that much of this technological progress disproportionately benefitted low-wage workers. If so, we should observe that most of the decline in inequality should have been concentrated during the Great Depression and the recession of 1937. We now argue this was indeed the case, first using evidence on wage inequality and then using evidence on income inequality.

[5] There is also evidence of increased human capital accumulation in the Depression that is more directly related to the channel we emphasize in our model. Goldin (1998) documents an unprecedented surge in high school enrollments and graduation rates between 1929 and 1932, similar to the increase in schooling in more recent recessions we described above. Once again, technology-specific skills are probably not accumulated by formal schooling, but the incentives to acquire such skills and the incentive to acquire general human capital are likely to be similar.

2.1.1. Wage Inequality

Unfortunately, there is no comprehensive data on the distribution of wages for the late 1920s. We instead draw on selected data compiled by economists writing in the wake of the Great Depression, as well as more recent archival work by economic historians. Our contribution lies not in offering new data, but in bringing together a variety of sources and providing a coherent framework to interpret them. The fact that certain measures of inequality fell during the Great Depression but not in other contractions was known for at least 50 years, and economists have always found this finding troubling. Our observation that the effects of the cycle depend on long-run trends allows us to make better sense of the data and resolve this puzzle.

We begin with the evidence on wage differentials within economic sectors. In this regard, Bernstein (1966) writes in his survey of the period

> There is some evidence that wage-cutting in the later years of the depression had a greater impact upon high than upon low rates, with the result that the extraordinarily wide differentials between the skilled and the unskilled that prevailed in 1929 were narrowed by 1933. The data are so skimpy that they merely suggest rather than confirm this conclusion. Between 1930 and 1932, according to BLS, the average hourly earnings of top and bottom classifications declines as follows: in boots and shoes, turn sewers' earnings decreased 29.1% in comparison to 21% for female table workers; in textile dyeing and finishing, machine engravers fell off 19.5% and female plaiters dropped 14.6%; in hosiery, footers' earnings declined 47.4% as winders' actually rose 7.1%; in men's clothing, cutters fell 19.2% as female examiners went down 16.1%; in motor vehicles, hammermen's earnings declined 20.4% in comparison to a drop of 47% for female laborers; in rayon mills, spinning bathmen fell 31.6%, but female truckers increased 9%. In all these cases, of course, the cents per hour decline for the top job far exceeded that for the bottom job. (p320-1).

Using richer BLS wage data drawn from unpublished sources, Dunlop (1939) also documents declines in the wage premia paid to skilled workers relative to unskilled workers between 1928 and 1932 in various manufacturing industries. In all eight industries for which he reports wages for common laborers, the median wages of laborers declined by a smaller percentage than the median wages of at least one category of more skilled workers within the same sector, and typically by less than all skilled workers within that industry. For example, between 1928 and 1932, the median nominal wage of common laborers in the automobile industry fell by only 4.0%, whereas the wages of other job categories in the same sector fell by $11.2 - 28.3\%$; the median nominal wage of laborers in blast-furnace plants declined by 22.2% compared with declines of

$23.2 - 28.1\%$ for remaining job categories; in open-hearth plants, the median wages of laborers fell by 19.8% compared with $30.0 - 39.9\%$ for other job categories; and in the cement industry, median nominal wages of laborers declined by $20.0 - 23.6\%$, compared with $20.1 - 28.6\%$ for other job categories.[6,7]

Further evidence that skill differentials within industries declined over this period comes from Dighe (1997), who uses survey data from the National Industrial Conference Board (NICB) for 25 manufacturing industries. He reports that relative to 1929, the average nominal wage of unskilled workers in all industries declined by 4.8% by September 1931, compared with 6.1% for skilled and semi-skilled workers. The same data suggests that the relative gain of unskilled labor was reversed as the economy began to recover, and by June 1933 the wages of both groups fell by virtually the same percentage relative to their 1929 average.[8] The gains of low-wage unskilled labor relative to skilled and semi-skilled labor in the depths of the Great Depression is remarkable. First, it is astonishing that unskilled labor, which by definition is easily replaceable, succeeded in achieving relative gains despite the increase in the number of unemployed workers during this period. Moreover, unskilled workers managed to avoid large wage cuts without the aid of labor unions, which as we discuss below had very weak legal standing until later on in the decade. The wage gains of unskilled labor in this period must therefore reflect either the generosity of employers towards low-wage workers, or, as our model suggests, technological improvements that allowed employers to pay unskilled labor relatively higher wages.[9]

[6]These figures come from Table 2 of Dunlop (1939). We should also note that Dunlop finds that over the same period, in 11 out of the 14 industries he examines, the wage gap between the top quartile and the bottom quartile of male wage-earners within a given industry increased. This is not necessarily inconsistent with our model, since wage compression in our model will tend to be concentrated at the top of the wage distribution, which may be above the top quartile of the wage distribution.

[7]Interestingly, unskilled labor achieved the smallest relative wage gains in lumber, which Bernstein (1987) identifies as having invested little in technical change during the Great Depression, and the largest relative gains in iron and tin, which invested a great deal in innovation.

[8]Dighe (1997) breaks down wage changes for each of the 25 manufacturing industries in the NICB data. Unskilled male workers gain relative to skilled and semi-skilled in 10 out of the 25 industries, and female workers gain relative to skilled and semi-skilled workers in 11 out of 22 industries. The same results are reported by Bell (1951), who finds skill premia declined in 6 out of 10 industries between 1928 and 1932 in NICB data.

[9]Bell (1951) argues social pressures might have compelled employers to spare unskilled labor from large wage cuts. But since all measures imply unemployment in 1929 and 1930 was below 12%, it is hard to explain why employers were so generous to laborers in these years given the wage cuts for unskilled labor in 1920-21 when unemployment was above 15%. Piketty and Saez (2001) also argue social norms can account for changes in the distribution of income over the century, but do not discuss the Depression in particular.

Since all of the evidence on wage inequality above concerns the period of the Great Depression between 1929 and 1932, they cannot be used to address the question of whether the Great Depression involved a more rapid compression of wage earnings as our model predicts. Luckily, Bell (1951) considers this exact question, and confirms our observation. He begins his discussion with the following observation:

> The prevalent feeling concerning movements in occupational wage differentials in the United States seems to be that there has been a trend toward a narrowing of the percentage differential between skilled and unskilled workers during the past half-century, and that this trend is accentuated in boom periods of full employment and reversed in depressions. This article has a threefold purpose [which includes] pointing out an important exception to the conventional model (the depression of 1929-33). (p329)

Bell reports his results only in abbreviated form, and so we can only cite his conclusions rather than his data. However, at one point, Bell does report that the gap between wages of skilled and semi-skilled workers in the NICB was constant between 1933 and 1936, the last year in which NICB data were available. By comparison, recall that Dighe (1997) finds this gap fell between 1929 and 1931 using the same NICB data.

We next consider wage differentials *across* sectors. Comparing wages across sectors is not quite in the spirit of our model in which workers assimilate the same set of skills; after all, bricklayers, no matter how much they make use of the new technology, will never become neurosurgeons. But our analysis would still apply if workers each applied the new technology in their own respective occupations, and workers in higher paying professions tended to assimilate it more quickly. Of course, the use of relative wages from different industries and occupations is subject to important caveats. First, the wage rates for particular groups may be affected by circumstances specific to those groups that are neither representative of changes in the earnings of a particular wage percentile nor related to productivity growth associated with the integration of new technologies. Second, our results might simply reflect the fact that workers in low-wage sectors are disproportionately laid off during contractions. We can offer no evidence to rule out this hypothesis, but it is noteworthy that some of the compression at the top of the distribution we describe below occurred in the early years of the Great Depression when unemployment was still fairly low – below 9% prior to 1931 – and comparable to earlier contractionary periods in which such gaps increased, while such composition effects would presumably have been more pronounced at high unemployment.

Our evidence on occupational wage differentials comes primarily from Williamson and Lindert (1980), who construct data on relative wages for self-employed physicians, associate professors, public school teachers, skilled workers in building trades, and skilled workers in manufacturing, all expressed relative to the wage rates of unskilled workers. Goldin and Margo (1992) construct additional wage series for the relative pay of skilled workers in the railroad industry, as well as for clerical workers in New York State. Since these wage series together cover a diverse set of occupations, we can potentially use the wages from different occupations as proxies for the different wage percentiles. Figure 2 illustrates the wage ratios for these various occupations.

As can be seen from Figure 2, the wages of physicians rank systematically at the top, followed by associate professors, clerks, teachers, and skilled workers in building trades and manufacturing. Given that unskilled labor are among the lowest wage earners, Figure 2 should be analogous to the region we identify as the area of decreasing inequality in Figure 1(b). Indeed, the paths of relative wages from the onset of the Great Depression bear close resemblance to the right half of Figure 1(b): the distribution of wages becomes compressed at the top but fans out at the bottom. As is obvious from Figure 2, all groups gain relative to the highest-wage group, physicians.[10] But the extent of compression is not limited only to physicians. For example, clerks register wage gains at the height of the Depression not only relative to the very top group, physicians, but also relative to the next highest group, professors: their wages rose from 57% of the wage of professors in 1929 to 73% by 1933, then remained at roughly this level until the end of the decade. Finally, between 1932 and 1941, unskilled workers gained relative to many of the higher paid occupations. Thus, the period between 1929 and 1941 appeared to involve both increasing and decreasing inequality across subgroups, with compression at the top of the wage distribution accompanied by a greater fanning out at the bottom. Moreover, from Figure 2, the compression at the top of the wage distribution seems to be concentrated in the downturns of 1929 and 1937 as suggested by our model, although this is driven primarily by the relative wage series of a few occupation groups.

[10] A natural concern is whether this decline reflects a drop in demand for physician services rather than wage patterns due to channels we describe. Stevens (1989) reports demand for physician services actually increased during the Great Depression: "Overall, despite the increased burden of free care, hospitals fared less badly than many other sectors of the economy... the average general hospital grew from 84 beds in 1929 to 104 in 1940. And although patient payments to nongovernmental hospitals and sanitoria (of all types) declined by 17 percent between 1929 and 1933, this was less than half the decline in consumer expenditures as a whole. Patient payments to governmental hospitals of all types actually increased by 21 percent between 1929 and 1933, as local general hospitals and state and local psychiatric hospitals sought free-paying patients. None of these figures, moreover, includes adjustments for declining prices" (p148-9).

2.1.2. Income Inequality

We next turn to changes in income inequality for the period between 1929 and 1941. Recall that our model implies that changes in income inequality among employed workers will mirror changes in wage inequality once the new technology is sufficiently diffused, except for small discrepancies that are likely to be unimportant at annual frequencies. Unlike wage data, income data is relatively abundant for the time period we are interested in. The most well-known source on income data is Kuznets (1953), who relies on federal income tax returns. Such data may be biased because of incentives to misreport income to tax authorities, as well as because certain job categories are exempt from taxes and therefore not recorded. But as we discuss below, similar patterns can be found using other data sources that are immune to such problems. One potential shortcoming of Kuznets' data, at least for our purposes, is that it relies on a broad notion of economic income that includes wages and salaries as well as income from rents and dividends, although it does not include capital gains and so is not directly affected by the stock market crash of 1929. Since the benefits of technological progress may accrue to dividend holders as well as wage earners, it is not obvious that economic income is not the relevant income measure. However, we argue below that the pattern of declining income inequality we document is also apparent in income derived from labor alone.

Recall from our model that among continuously employed workers, the incomes of those at the top of the distribution will be the first to fall relative to lower-income workers, while the income of those further down the distribution may only begin to fall later on. Consequently, we should observe a systematic decline in the share of the total income of all continuously employed workers that accrues to the very top income recipients, but perhaps not among the income shares of lesser-income earners. In his volume, Kuznets reports the share of *national* income that accrues to the top percentiles of the U.S. population. This approach is biased against finding evidence of declining inequality in downturns, since the fall in income from the rise in unemployment would tend to increase the share of top income groups who are less vulnerable to unemployment. Nevertheless, Figure 3 shows that the income share of the top 1% steadily declined between 1929 and 1941, including during the years of the Great Depression between 1929 and 1932. The income shares of the top 2-3% and 4-5% also decline, but only starting in 1932.

As can be seen from Figure 3, most of the decline in the income share of the top 1% occurs during the Depression itself, i.e. between 1929 and 1932. There is a second fall associated with the recession of 1937. The differences in the rates of decline are summarized in Table 1, which is taken directly from Kuznets (1953). This table reports changes in the share of economic income of upper income groups. Between 1929 and 1932, the share of the top 1% declined at a rate of 0.53% per year. In the subsequent recovery between 1932 and 1937, it actually increased slightly at an average rate of 0.02% per year. In the next contraction between 1937 and 1938, the share of income of the top 1% fell by 1.46% per year, while in the subsequent recovery it fell by 0.48% per year. For the top 5% of all taxpayers as a whole, the Depression was associated with only a small decline in their share of total income, much smaller than the decline in inequality in the subsequent recovery. But the contraction of 1937-1938 was associated with a sharp decline in the income share of this group that exceeded the decline in the subsequent expansion: 1.13% per year compared with 1.02% per year.[11]

For further evidence that the acceleration in the decline of the top income share was concentrated in periods of economic contraction, we next turn to Schmitz and Fishback (1983), who disaggregated Kuznets' federal income tax data by states. That is, they computed the share of income in each state that went to the top percentile of individuals residing in that state. Of the 43 states in which the income share of the top 1% declined between 1929 and 1933, this share declined more between 1929 and 1933 than between 1933 and 1939 in all but one. This is partly due to the fact that the income share of the top 1% reversed in some states as their relative income recovered. But in 28 of the 43 states in which the income share of the top 1% declined between 1929 and 1932, the income share of this group continued to decline to below its 1933 level by the end of the decade, just at a slower pace. A similar picture emerges for the income share of the top 2-5%: in 6 out of the 9 states for which the share of income of this group declined between 1929 and 1933, the decline in the Depression years was greater than the change in the income share of this group in the subsequent recovery. The bulk of the decline in the share of the very top income groups appeared to take place in the Depression.

[11] Our interpretation of Kuzents' data is quite different from McLean (1991). McLean regresses the share of income of the top 1% from starting from 1919 on aggregate unemployment and a time-trend, and finds only a weak negative relationship between this income share and unemployment. However, our approach suggests treating the 1920s and 1930s differently given the differences in trend inequality over these periods. When we repeat McLean's regression using data only from 1929 on, we find a significant negative partial correlation between the income share of the top 1% and unemployment measures. The significant negative coefficient on unemployment emerges regardless of whether we use the NBER macroeconomic historical database (which is based on NICB data), the unemployment series reported in Lebergott (1964), and a corrected version of the Lebergott series constructed by Darby (1976) that excludes workers employed on work-relief.

The fact that only the income shares of the very rich decline during the Depression raises concerns as to whether this pattern is due to the collapse of dividend income from 1929 on, as opposed to changes in the distribution of labor income as in our model. We now present evidence that this is not the case. First, consider Table 123 in Kuznets (1953), which reports the share of aggregate labor income that accrued to those in the top 1% ranked by economic income. This share is depicted graphically in Figure 4 below. As apparent from the figure, this share declined from 8.7% in 1928 to 7.9% in 1931, and stayed at roughly this level until 1938. Hence, at least part of the reason why the earnings of the very rich fell relative to those further down in the distribution was that they were earning relatively less labor income than before.

Next, we turn to evidence on the distribution of earnings derived from labor income. In a recent paper, Piketty and Saez (2003) construct the distribution of wage and salary income using the same tax data that Kuznets used. Their construction omits entrepreneurial income, and so is not exactly equivalent to labor income. Nevertheless, it provides evidence on changes in the distribution of incomes based solely on labor income. In constructing their data, Piketty and Saez report the fraction of all wage and salary income that accrues to various percentiles of all wage-earners in a given year. Note the difference from Kuzents' approach, which considers percentiles of the *entire* population. As a result, the number of individuals that Piketty and Saez count in a given percentile is not constant over time, and changes in the income share of the top 1 percentile may reflect changes in the number of people in that group rather than changes in relative earnings. To get around this problem, we consider changes only in the very top of the distribution. If the distribution of income belongs to the class of Pareto distributions, then to a first approximation, the ratio of the income of the top $n\%$ of all wage earners to the top $m\%$ of all wage earners for $m > n$ depends on the ratio $\frac{n}{m}$ and not on the number of wage earners. Since Piketty and Saez argue that the income distribution resembles a Pareto distribution at high income levels, we consider the ratio of the income of the top 1% to that of the top 5%. Just as with total income, the share of labor income among the top 1% falls during this period, from a high of 44.8% in 1928 to 42.1% in 1932, and continues to decline at a slower average rate for the rest of the decade, reaching 41.7% by 1940.

Given the problems inherent in using income data from tax returns, we now consider a study by Mendershausen (1946) which covers the same time period using different data series. For most of his analysis, Mendershausen uses data from the Financial Survey of Urban Housing.

The survey was administered by the Civil Works Administration to inhabitants of dwelling units in 61 large and middle-sized cities. The survey questions include income data (including both labor and non-labor sources) in 1929 and in 1933 for the same set of households. Mendershausen was able to obtain data for 33 cities.[12] Depending on the size of city, his samples vary between 4.4% and 34.9% of the estimated number of dwelling units in a given city. While this survey is potentially subject to non-response bias, it is immune to the criticisms that plague tax return data such as the incentive to misreport income and the exclusion of certain job categories. Mendershausen computes Lorenz curves for households of all income levels in each city. These curves reveal a similar pattern as the federal income tax data: the share of total income that accrues to those at the very top of the distribution declines between these two periods. Specifically, Mendershausen finds that the share of income that accrue to the top income earners declined in 21 of the 33 cities in his sample. Mendershausen computes to within 10% the point at which the share of total income belonging to the top group of income earners begins to rise rather than fall. In 15 of the 21 cities, the income share of top income recipients declined for the top $1-10\%$. In 5 cities, the share declined for the top $10-20\%$ of all income earners, and in one city the income share declined for the top $20-30\%$ of all income recipients.

Mendershausen then goes on to show that disparities within the group of top income recipients declined over this period. He computes a coefficient of concentration – basically a Gini coefficient – for households reporting an annual income above $2000 in 1929. In most cities, this group represents the top 30% of income earners. In 24 of the 33 cities, inequality among high income households as measured by the coefficient of concentration decreases between 1929 and 1933. Thus, even in cities where the share of top income earners did not appear to decline between these two years, there is still evidence of compression at the top of the income distribution. This is probably because excluding low income households mitigates the effects of unemployment on the distribution of income that tend to obscure the compression of incomes at the top of the distribution. Experimenting with raising the cutoff to $3000, or the top 15-20% of all households, implies inequality at the top of the distribution declined in even more cities.[13]

[12] The cities he considers are Atlanta, Birmingham, Boise, Butte, Cleveland, Dallas, Des Moines, Erie, Indianapolis, Lansing, Lincoln, Little Rock, Minneapolis, Oklahoma City, Peoria, Portland (Maine), Portland (Oregon), Providence, Racine, Richmond, Sacramento, St. Joseph, St. Paul, Salt Lake City, San Diego, Seattle, Springfield (Missouri), Syracuse, Topeka, Trenton, Wheeling, Wichita, and Worcester.

[13] Once again, our interpretation of Mendershausen's data contradicts the one reached by McLean (1991). The reason for this difference is that McLean focuses on the income distribution as a whole rather than delineating

As further corroboration, Mendershausen examines supplementary state income tax data for two states, Wisconsin and Delaware. These state income tax returns are superior to the federal income tax returns because of their expanded coverage: in Delaware every resident was required to file a tax return, while in Wisconsin only high income households were required to file a tax return, but the threshold was lower than the federally mandated one. For Wisconsin, he compiles data for 1929 and the years 1934-1936, and for Delaware he compiles data for the years 1936-1938. Turning first to the income shares of the top income earners, Mendershausen's data reveals that in Wisconsin, the share of total taxpayer income that accrued to the top 25% of all taxpayers declined between 1929 and 1934. In Delaware, the evidence is even more extreme: the share of income at all deciles declined between 1937 and 1938, i.e. the bottom income group managed to gain relative to all above them who earned a higher income in the second contraction.

With regards to disparities among the top income recipients, the state income tax data again confirms a general decline over this period that was particularly concentrated in contractions. He computes a Gini coefficient for all individuals above an income threshold of $2000 in 1929 for Wisconsin. This group constitutes the top third of all taxpayers in 1929. Limiting attention to this group of households, the Gini coefficient declined from 0.317 in 1929 to 0.254 in 1934. By 1935, in the midst of the economic turnaround, the Gini coefficient fell just slightly to 0.252, and by 1936 it reversed course and increased to 0.283. In Delaware, Mendershausen once again divides the data based on whether individuals reported an income in 1936 above a threshold of $2000, which yields the top 19% of all taxpayers in 1936. This group likewise exhibits a more pronounced decline in inequality during the recession: between 1936 and 1937, the Gini coefficient declined from 0.621 to 0.589, while between 1937 and 1938 when the economy was in recession, it fell more sharply to 0.519.

2.1.3. Can Policy Account for Declining Inequality during the Depression?

Before we turn to the evidence on cyclical fluctuations in periods of rising inequality, we briefly consider the possibility that the unusual behavior of inequality during the downturns of the

between the upper part and lower part of the income distribution. As suggested by our model, the decline in earnings disparities at the top of the distribution can be accompanied by an increase in disparities further down the distribution.

1930s was instead due to unprecedented government intervention during this era. Much of the decline in the relative earnings of those at the top of the distribution occurred during the downturn between 1929 and 1932, when many of the forces that could have potentially brought about declining wage gaps would not have been present. The Hoover administration intervened in labor markets only to a limited extent. Appointed commissions such as the President's Emergency Committee for Employment and later the Teagle Committee advocated in favor of shortening work shifts and spreading the work across workers, although this was never codified. In principle, such work-sharing arrangements could contribute to reducing income inequality. Moreover, as Bernanke (1986) argues, employers might be reluctant to cut the incomes they pay workers too much, in which case work sharing would have contributed more to the decline of the incomes of high-wage workers than among low wage workers. But work-sharing was not widely adopted until later in the Great Depression, and was incorporated into law only with the adoption of the National Industrial Recovery Act (NIRA) under the Roosevelt administration in 1933. But recall that much of the compression in the distribution of earnings occurred in the early years of the Great Depression, suggesting it had little to with work-sharing.

Other forms of government intervention involved restrictions on immigration intended to alleviate the rising tide of unemployment, which should have raised the relative wage of unskilled workers given many immigrants at the time were unskilled. But legislation to limit immigration was enacted long before the Depression, and Congress voted to allocate additional resources to enforcement of immigration laws only in 1932. Government regulation also helped to strengthen the labor movement during this decade, which again could have contributed to lowering inequality since unions tended to organize unskilled workers. However, union activity was fairly minimal prior to 1933, and most of the major industries were unionized only later during the decade. The legal protection unions received was only part of the New Deal, which came too late to account for the decline in inequality during the Great Depression. For example, the Norris-LaGuardia Anti-Injunction Act which precluded employers from forcing workers to commit not to organize was passed only in 1932. The main boost to the labor movement came with the passage of the NIRA in 1933, and then again with the passage of the National Labor Relations Act (NLRA) in 1935. If anything, the fact that government intervention under the New Deal facilitated wage compression in the latter part of the decade makes the sharper decline of inequality prior to 1932 seem even more striking.[14]

[14]Bell (1951) similarly rejects the role of labor unions and government policies; see especially pages 333-5.

2.2. Eras of Rising Earnings Inequality

We next briefly discuss the two periods of rising inequality in the past century, to highlight that the effect of business cycles on the same measures of inequality was exactly the opposite as it was during the period of the Depression. This includes both the past four decades as well as the period of rising inequality prior to the Great Depression. The virtue of using data from a period of rising inequality prior to the Great Depression is that it can help address the claim that pre-War business cycles were inherently different than post-War business cycles. For example, Bernanke and Powell (1986) offer evidence that wages tended to be more procyclical in the post-War period than in the pre-War period, suggesting differences in the way labor markets operated in the pre-War period. The evidence below reveals that recessions did contribute to greater inequality in the pre-War period, but only when long-run inequality was increasing.

2.2.1. Rising Inequality in the pre-War Era

The period from the early 1910s to the late 1920s was marked by a dramatic increase in earnings inequality, driven in part by the effects of new technologies and production methods made possible by the commercialization of electricity. For example, Williamson and Lindert (1980) report that by 1929, "gaps between traditionally high-paid and low-paid jobs were almost as wide as in 1916, when the widest gaps in American history seem to have prevailed." (p81).

Turning first to measures of wage inequality, there unfortunately is not much reliable evidence concerning the behavior of skill premia prior to the Great Depression. One exception is the survey by Bell (1951) of over 600 occupations in various industries, drawing wage data for various industries using BLS, NICB, the Department of Commerce and the Interstate Commerce Commission. He argues that recessions tended to increase occupational wage differentials, with the Depression of 1929-33 serving as an important exception. Summarizing his findings, based on data which unfortunately are not reported in his article, he notes that during the recession of 1920-1921, "six of the eight industries for which BLS and other government material is available experienced a widening of the spread" whereas "during the Great Depression a decade later, none of the 16 industries surveyed by BLS experienced a definite widening of occupational differentials" (p332). With regard to wage differentials across sectors, here too there is some evidence that wage differentials tended to increase during recessions prior to 1929. For example, Williamson and Lindert (1980) argue that during the 'uneven plateau' between the Civil War to the Great Depression, the wages of various occupation groups relative to those of unskilled labor we examine in Figure 4 appear to be countercyclical. Prior to 1929, they note that

> Like our measures of income dispersion, the pay ratios show a generally counter-cyclical pattern. The pay ratios tend to drop in booms and to rise in recessions. This tendency is much more pronounced when the boom or contraction comes rapidly than when it takes a few years to gather momentum. (p82)

The evidence on income inequality, for which more comprehensive data is available, also offers a case for the uniqueness of the 1930s. As Table 1 illustrates, contractions earlier in the century, which occurred when the income share of the top 1% was generally increasing, were associated with faster growth in the share of the top 1%. This observation is based on the same data sources which point to declining inequality during the Great Depression. Kuznets himself commented on the puzzling lack of consistency in the direction of these shares over the cycle and called for further work on this question. Moreover, as demonstrated in Figure 4, the uniqueness of the Great Depression does not simply reflect the dramatic decline in dividend income during this time. In all four contractions prior to 1929, the share of service incomes (compensation and entrepreneurial income) of the top 1% of all income earners ranked by economic income tended to rise. By contrast, their share of labor incomes in both the Great Depression and the recession of 1937 tended to fall.

2.2.2. Rising Inequality in the Post-War Era

Evidence on income inequality for the post-War period has been studied by a variety of different authors. We therefore provide only a brief overview of the results to emphasize the comparability of their measures to the measures we focus on in studying the Great Depression, rather than explore these results in detail.

In terms of wage data, there is surprisingly little work on wage inequality over the cycle; instead, most work on the evolution of wages over the cycle has emphasized the behavior of average wages and whether these are procyclical or countercyclical. A few of these papers note in passing that wages are more procyclical for low-wage workers than for high wage workers, which would suggest recessions would increase wage dispersion. Rubinstein and Tsiddon (2000) explicitly consider the distribution of wages over the cycle, and find that in the modern era, low-skill and low-wage workers suffered disproportionately large wage cuts in contractions. Thus, the same measure of wage dispersion that appears to fall during the Great Depression rises in more recent recessions.

Turning to measures of income inequality, much of the evidence focuses on the behavior of the income share of the top income earners of the population. For example, Blinder and Esaki (1978), Blank and Blinder (1986), Burtless (1990), and Cutler and Katz (1991) all argue that recessions foster inequality by appealing to the fact that the income share of the top 20% of all households has tended to rise in post-War recessions. This is not directly comparable to the top 1% of households that Kuznets (1953) considers. However, recall that Mendershausen's analysis finds several instances in which the income share of the top 20% that fell during the Great Depression, e.g. in several of the cities in his study as well as in both the Wisconsin and Delaware state income tax data. Once again, the same measure of inequality that rises during recessions in recent periods seemed to fall during the Great Depression.

To summarize, the accelerated decline in relative wages and income shares of those at the top of the distribution appears to be unique to the contractions of the 1930s, and goes against the pattern of rising inequality in contractions during both the pre-Depression and post-War period. Since the Great Depression was such a unique episode in economic history, it is difficult to assess whether this pattern is due to the difference in long-run trend inequality during this period, as our model would suggest, or whether this is just another way in which the Great Depression was different from any other recession. But regardless of the true reason for the unusual patterns in earnings inequality that appear during this period, our findings certainly raise questions about the presumption in recent work in macroeconomics that views recessions as systematically contributing to greater earnings disparities.

3. Conclusion

Our motivation in this paper is to call attention to the fact that most of the recent work on changes in earnings disparities over the cycle is disconnected from changes in long-run inequality. We find this practice to be unsatisfactory, and demonstrate this by showing how fluctuations interact with the forces that drive long-run inequality. According to the mechanism we outline, recessions should contribute more to raising inequality when inequality is rising over the long run than when it is falling. Evidence from the first half of the 20th century supports our contention that the cyclicality in earnings inequality is not uniform, and instead depends on the direction of trend inequality.

Of course, ours is but one way in which cyclical fluctuations affect the distribution of earnings; other factors, such as changes in the incidence of unemployment, search and matching, dynamic contracting, and so on, all affect earnings over the business cycle, and are all important in ultimately shaping the distribution of earnings. Our goal here is not to present a comprehensive model to account for all of the changes in the distribution of earnings over the cycle. Rather, it is to illustrate that if we wish to identify and measure the effect of cyclical fluctuations on inequality, we need to take into account how such fluctuations interact with long-run changes in the distribution of earnings; otherwise, changes in inequality over the cycle are measured in a biased way. Our analysis thus suggests that accounting for long-run changes in measures of inequality requires more than just allowing for a time trend, since cyclical fluctuations can have a different impact on the distribution of earnings when inequality is generally rising than when it is falling. Instead, we need to explicitly model the evolution of long-run inequality, even if we are only interested in studying cyclical phenomena.

Finally, the fact that trends can influence the degree of cyclical sensitivity of earnings inequality has important implications for using evidence on the cyclicality of earnings inequality in resolving various macroeconomic puzzles. The source of changes in earnings inequality over the cycle we focus on in this paper has nothing to do with income risk, and is instead driven by the endogenous decisions of agents. Since at least part of the increase in inequality observed during the recessions of the past three decades probably captures the effects of cyclical fluctuations on the same endogenous decisions that lead to rising inequality rather than as evidence of greater income volatility, calibrating income volatility to earnings data compiled from a period of rising inequality as previous work has implicitly done would tend to overstate the true increase in income volatility during downturns (just as it would tend to understate the true increase if estimates were based on a period of decreasing inequality). While it is not obvious how large this bias is, the historical evidence we reviewed here suggests trends may play enough of a role that they can be discerned in the earnings data, and so the implications for estimates of income volatility need not be negligible.

Appendix

Proof of Proposition 1: Let us rewrite (1.7) with x as a function of t rather than s_t. To do this, let us rewrite $\dot{s}$ in terms of x as follows:

$$\begin{aligned}
\dot{s} &= a\,(sn)^b \\
&= a\left(\frac{ab}{Z}V'(s)\right)^{\frac{b}{1-b}} \\
&= a\left(\frac{ab}{Z}\left[x'(s)+\frac{Z}{\rho}\right]\right)^{\frac{b}{1-b}} \\
&= a\left[\frac{ab}{Z}\left(\frac{\rho x(s)}{m}\right)^{1-b}\right]^{\frac{b}{1-b}}
\end{aligned}$$

where $m = \dfrac{1-b}{b}\left[\dfrac{ab}{Z^b}\right]^{\frac{1}{1-b}}$. This last expression simplifies to

$$\dot{s} = a\left[\frac{\rho b x(s)}{(1-b)\,Z}\right]^b$$

We use this to write out the law of motion for $\dfrac{dx}{dt}$ as follows:

$$\begin{aligned}
\frac{dx}{dt} &= \frac{dx}{ds}\cdot\frac{ds}{dt} \\
&= \left[\left(\frac{\rho x}{m}\right)^{1-b}-\frac{Z}{\rho}\right]\cdot a\left[\frac{\rho b x}{(1-b)\,Z}\right]^b \\
&= a\left[\frac{b}{(1-b)\,Z}\right]^b m^{b-1}\rho x - a\left(\frac{Z}{\rho}\right)^{1-b}\left(\frac{bx}{1-b}\right)^b \\
&= \frac{\rho}{1-b}x - \left[a\left(\frac{Z}{\rho}\right)^{1-b}\left(\frac{b}{1-b}\right)^b\right]x^b
\end{aligned}$$

This yields a non-linear differential equation for $x(t)$ known as a Bernoulli equation, which can be solved in closed form. Simply define $y = x^{1-b}$ and rewrite the above equation as

$$\frac{dy}{dt} = \rho y - \left[a\left(\frac{(1-b)\,Z}{\rho}\right)^{1-b} b^b\right]$$

which has the solution

$$y = \left[\frac{a}{\rho}\left(\frac{(1-b)\,Z}{\rho}\right)^{1-b} b^b\right] + Ce^{\rho t} \tag{3.1}$$

for some constant C. Since $y_t > 0$ for $t = 0$ but $\lim_{t\to\infty} y = 0$, it follows that $C < 0$ and that $\dot{y} \leq 0$ for all t. Using the fact that

$$\dot{s} = a\left[\frac{\rho b}{(1-b)\,Z}\right]^b y^{\frac{b}{1-b}}$$

and the fact that $\dot{y} < 0$, it follows that $\ddot{s} < 0$, establishing s is concave in t. The fact that $C < 0$ insures there exists a finite T for which $y_T = 0$.

Finally, to show that the paths s_{it} and s_{jt} for $a_i > a_j$ do not cross, note that since the option to learn must be more valuable for those who are more able, $y_i \geq y_j$ whenever $s_i = s_j$. Hence, if there exists a date t' s.t. $s_{it'} = s_{jt'} \neq \overline{s}$, it must be true that $\dot{s}_{it'} > \dot{s}_{jt'}$ at date t'. Since $s_{i0} = s_{j0} = s_0$, it follows that $\dot{s}_{i0} > \dot{s}_{j0}$, and so $s_{it} > s_{jt}$ within a neighborhood of $t = 0$. Now, suppose there was some date $t' > 0$ s.t. $s_{it'} = s_{jt'} \neq \overline{s}$, and w.l.o.g. suppose this is the first such date at which this occurs. Since $s_{it} > s_{jt}$ for all $t \in (0, t')$, it must be the case that $\dot{s}_{it'} < \dot{s}_{jt'}$, which is a contradiction. ■

Proof of Proposition 2: For an individual with skill level $s < \overline{s}$, the asset equations are given by

$$\rho V_k(s) = \max_n \left\{ Z_k s (1-n) + V_k'(s)\, a\,(sn)^b + \mu \left[V_{-k}(s) - V_k(s) \right] \right\}$$

Taking the first order condition with respect to n and substituting in yields

$$\rho V_k(s) = Z_k s + m_k \left(V_k'(s) \right)^{\frac{1}{1-b}} + \mu \left[V_{-k}(s) - V_k(s) \right] \tag{3.2}$$

where $m_k = \dfrac{1-b}{b} \left(\dfrac{ab}{Z_k^b} \right)^{\frac{1}{1-b}}$. Once again, let $x_k(s)$ denote the value of the option to learn additional skills

$$x_k(s) = V_k(s) - \frac{(\rho+\mu) Z_k + \mu Z_{-k}}{\rho(\rho+2\mu)} s$$

and rewrite the system of differential equations for $V_k(s)$ in terms of $x_k(s)$:

$$x_k'(s) = \left[\frac{(\rho+\mu)\, x_k(s) - \mu x_{-k}(s)}{m_k} \right]^{1-b} - \frac{(\rho+\mu) Z_k + \mu Z_{-k}}{\rho(\rho+2\mu)} \tag{3.3}$$

The above system of differential equations is defined only over the region $\left\{ (x_0, x_1) : \dfrac{\rho+\mu}{\mu} x_0 > x_1 > \dfrac{\mu}{\rho+\mu} x_0 \right\}$. The values of $x_k(s)$ along the optimal path solve the system of differential equations (3.3) together with the boundary condition $x_0(\overline{s}) = x_1(\overline{s}) = 0$.

Figure A1 depicts the phase diagram for (3.3). The region over which the system is defined corresponds to the unshaded region between the two rays $x_1 = \dfrac{\mu}{\rho+\mu} x_0$ and $x_1 = \dfrac{\rho+\mu}{\mu} x_0$. The condition that $\dfrac{dx_k}{ds} = 0$ implies $(\rho+\mu)\, x_k - x_{-k} =$ constant, so is parallel to the boundary of region in which the system is defined. The dynamics of (x_1, x_0) are indicated by the arrows. The optimal path is the unique path that goes through the origin, which corresponds to the boundary condition $x_0(\overline{s}) = x_1(\overline{s}) = 0$, and is depicted in the figure as a thick line.

Substituting in from the first-order condition, we can show that the rate at which skills are acquired along the optimal path for a particular realization of $z_t = Z_k$ is given by

$$\left.\frac{ds_t}{dt}\right|_{z_t=Z_k} = a\,(sn)^b = a\left(\frac{b}{1-b}\right)^b \left[\frac{\rho x_k\,(s) + \mu\,[x_k\,(s) - x_{-k}\,(s)]}{Z_k}\right]^b$$

It follows that $\left.\frac{ds_{it}}{dt}\right|_{z_t=Z_0} > \left.\frac{ds_{it}}{dt}\right|_{z_t=Z_1}$ if and only if $\frac{\rho x_0 + \mu\,[x_0 - x_1]}{Z_0} \geq \frac{\rho x_1 + \mu\,[x_1 - x_0]}{Z_1}$, or, upon rearranging

$$x_1 \leq \frac{(\rho+\mu)\,Z_1 + \mu Z_0}{(\rho+\mu)\,Z_0 + \mu Z_1}\,x_0 \tag{3.4}$$

which describes a region in (x_1, x_0) space whose boundary is a line with slope greater than 1 that cuts through the origin. The boundary is illustrated as the dashed line in Figure A1, and the region where agents acquire skills more rapidly during recessions is to the right of this half-line.

At $(x_0, x_1) = (0, 0)$, we can apply L'Hopital's rule to show that for the true values of learning $x_0\,(s)$ and $x_1\,(s)$, we have

$$\lim_{s\to\underline{s}} \frac{\rho x_0\,(s) + \mu\,[x_0\,(s) - x_1\,(s)]}{\rho x_1\,(s) + \mu\,[x_1\,(s) - x_0\,(s)]} = \lim_{s\to\underline{s}} \frac{\rho x_0'\,(s) + \mu\,[x_0'\,(s) - x_1'\,(s)]}{\rho x_1'\,(s) + \mu\,[x_1'\,(s) - x_0'\,(s)]} = \frac{Z_0}{Z_1}$$

This implies that the optimal path $(x_0\,(s)\,, x_1\,(s))$ is tangent to the line defined by (3.4) at $(0, 0)$, as illustrated in Figure A1.

Next, we show that the path $(x_0\,(s)\,, x_1\,(s))$ lies in the region defined by (3.4). Consider a path $(\widetilde{x}_0\,(s)\,, \widetilde{x}_1\,(s))$ that satisfies (3.3) for which there exists an $\widetilde{s}$ such that

$$\widetilde{x}_1\,(\widetilde{s}) = \frac{(\rho+\mu)\,Z_1 + \mu Z_0}{\mu Z_1 + (\rho+\mu)\,Z_0}\,\widetilde{x}_0\,(\widetilde{s})$$

and where

$$\widetilde{x}_0'\,(\widetilde{s})\,, \widetilde{x}_1'\,(\widetilde{s}) < 0$$

Using equation (3.3), we have

$$\begin{aligned}
\widetilde{x}_0'\,(\widetilde{s}) &= \left[\frac{(\rho+\mu)\,\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b} - \frac{(\rho+\mu)\,Z_0 + \mu Z_1}{\rho\,(\rho+2\mu)} \\
\widetilde{x}_1'\,(\widetilde{s}) &= \left[\frac{(\rho+\mu)\,\widetilde{x}_1 - \mu\widetilde{x}_0}{m_1}\right]^{1-b} - \frac{(\rho+\mu)\,Z_1 + \mu Z_0}{\rho\,(\rho+2\mu)} \\
&= \left[\frac{m_0}{m_1}\frac{(\rho+\mu)\,\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b} - \frac{(\rho+\mu)\,Z_1 + \mu Z_0}{\rho\,(\rho+2\mu)} \\
&= \frac{Z_1^b}{Z_0^b}\left[\frac{(\rho+\mu)\,\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b} - \frac{(\rho+\mu)\,Z_1 + \mu Z_0}{\rho\,(\rho+2\mu)}
\end{aligned}$$

Since $\widetilde{x}_k'(\widetilde{s}) \neq 0$, then for $s = \widetilde{s}$, we have

$$\begin{aligned}
\frac{d\widetilde{x}_1}{d\widetilde{x}_0} &= \frac{d\widetilde{x}_1/ds}{d\widetilde{x}_0/ds} \\
&= \frac{(\rho+\mu)Z_1 + \mu Z_0 - \rho(\rho+2\mu)\left[\frac{Z_1}{Z_0}\right]^b \left[\frac{(\rho+\mu)\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b}}{(\rho+\mu)Z_0 + \mu Z_1 - \rho(\rho+2\mu)\left[\frac{(\rho+\mu)\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b}} \\
&< \frac{(\rho+\mu)Z_1 + \mu Z_0 - \rho(\rho+2\mu)\left[\frac{(\rho+\mu)\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b}}{(\rho+\mu)Z_0 + \mu Z_1 - \rho(\rho+2\mu)\left[\frac{(\rho+\mu)\widetilde{x}_0 - \mu\widetilde{x}_1}{m_0}\right]^{1-b}} \\
&< \frac{(\rho+\mu)Z_1 + \mu Z_0}{(\rho+\mu)Z_0 + \mu Z_1}
\end{aligned}$$

where the two inequalities use the fact that $(\rho+\mu)x_1 - \mu x_0 > 0$. Thus, the slope of such a curve is lower than the line defined by (3.4). To show that the optimal path $(x_0(s), x_1(s))$ satisfies (3.4), we can now use a simple contradiction argument: if $(x_0(s), x_1(s))$ ever violated (3.4), it would require the path to have a steeper slope that $\frac{(\rho+\mu)Z_1 + \mu Z_0}{(\rho+\mu)Z_0 + \mu Z_1}$ along the line defined by (3.4) for the region where $x_k'(s) < 0$, which was we just proved is impossible. ■

Proof of Proposition 3: Suppose $\overline{s} = \infty$. The asset equations along the optimal path are still given by (3.2), but now the boundary condition is replaced with a transversality condition. Appealing to the method of undetermined coefficients, we can confirm that in this case the value function $V(s)$ is linear in s, and use this to solve directly for the law of motion

$$\left.\frac{ds}{dt}\right|_{z_t = Z_k} = a^{\frac{1}{1-b}} \left[\frac{b}{\rho}\frac{(\rho+\mu)Z_k + \mu Z_{-k}}{(\rho+\mu)Z_k + \mu Z_k}\right]^{\frac{b}{1-b}}$$

Since all agents start with the same skill level s_0, it follows that at $t = 0$, the wage ratio (which equals the skill ratio) is equal to 1. For $t > 0$, let $k(t) \in \{0, 1\}$ denote which state z_t assumes at date t. The skill level for individual i is then given by

$$\begin{aligned}
s_{it} &= s_0 + \int_0^t \left.\frac{ds_{i\tau}}{dt}\right|_{z_\tau = Z_{k(\tau)}} d\tau \\
&= s_0 + a_i^{\frac{1}{1-b}} \int_0^t \left[\frac{b}{\rho}\frac{(\rho+\mu)Z_{k(\tau)} + \mu Z_{-k(\tau)}}{(\rho+\mu)Z_{k(\tau)} + \mu Z_{k(\tau)}}\right]^{\frac{b}{1-b}} d\tau \\
&\equiv s_0 + a_i^{\frac{1}{1-b}} g(t)
\end{aligned}$$

where $g(t)$ is a function of the entire path $\{z_\tau\}_{\tau=0}^t$. For any such path, $g(t)$ is increasing in t given that $\min_k \left(\frac{b}{\rho}\frac{(\rho+\mu)Z_{k(\tau)} + \mu Z_{-k(\tau)}}{(\rho+\mu)Z_{k(\tau)} + \mu Z_{k(\tau)}}\right) > 0$, $\lim_{t\to\infty} g(t) = \infty$, and $g(t)$ is continuous in t. Given that $a_i > a_j$, it follows that the skill ratio

$$\frac{s_{it}}{s_{jt}} = \frac{s_0 + a_i^{\frac{1}{1-b}} g(t)}{s_0 + a_j^{\frac{1}{1-b}} g(t)}$$

is increasing in t for any realized path, and that in the limit, the ratio converges to $\left(\frac{a_i}{a_j}\right)^{\frac{1}{1-b}}$. Differentiating with respect to t and using the fact that $g'(t) = \left(\frac{b}{\rho}\frac{(\rho+\mu)\, Z_{k(t)} + \mu Z_{-k(t)}}{(\rho+\mu)\, Z_{k(t)} + \mu Z_{k(t)}}\right)$ is higher when $k(t) = 0$ establishes the second part of the claim. ■

Proof of Proposition 4: To show that $s_{it} \geq s_{jt}$, recall from the proof of Proposition 3 that when aggregate productivity is equal to Z_k, the change in skills is given by

$$\left.\frac{ds_t}{dt}\right|_{z_t=Z_k} = a\left(\frac{b}{1-b}\right)^b \left[\frac{\rho x_k(s) + \mu\left[x_k(s) - x_{-k}(s)\right]}{Z_k}\right]^b$$

Fix the value of s, and consider the two individuals i and j. For the individual with the higher ability, we know that a is higher. We need to show that $\rho x_k(s) + \mu\left[x_k(s) - x_{-k}(s)\right]$ is increasing in a. But $\rho x_k(s) + \mu\left[x_k(s) - x_{-k}(s)\right]$ is just the flow value of the option to accumulate skills beyond s, i.e. it is equal to

$$\max_n \left\{\left[Z_k s'(1-n) - Z_k s\right] + \frac{dx_k}{ds'} a\left(s'n\right)^b\right\}$$

But agents with higher a benefit more from learning, this expression must be increasing in a. Hence, a given level of $s < \overline{s}$, $\left.\frac{ds_t}{dt}\right|_{z_t=Z_k}$ is strictly increasing in a for both values of k, i.e. starting from the same skill level, the more able worker will accumulate more skills. By a similar argument to the proof of Proposition 1, one can show that $s_{it} > s_{jt}$ if $s_{it} \in (s_0, \overline{s})$.

Next, we establish that an individual still reaches $\overline{s}$ in finite time, i.e. there exists a time T such that for any realization z_t where $t \in [0, \infty)$, $s_t = \overline{s}$ for $t \geq T$. We do this by proving that if either $k = 0$ or $k = 1$, the individual would reach $\overline{s}$ in finite time. It follows from this that for any realization z_t, the individual would reach $\overline{s}$ in finite time.

Let $y_k \equiv (\rho+\mu)\, x_k(s) - \mu x_{-k}(s)$. Combining the evolution of $x_k(s)$ and s_t yields the following law of motion for x_k as a function of t conditional on $z_t = Z_k$:

$$\begin{aligned}
\left.\frac{dx_k}{dt}\right|_{z_t=Z_k} &= \frac{dx_k}{ds}\cdot\left.\frac{ds}{dt}\right|_{z_t=Z_k} \\
&= \left(\left(\frac{y_k}{m_k}\right)^{1-b} - \frac{(\rho+\mu)\, Z_k + \mu Z_{-k}}{\rho(\rho+2\mu)}\right) a\left(\frac{b}{1-b}\right)^b \left[\frac{y_k}{Z_k}\right]^b \\
&= \frac{a}{m_k}\left(\frac{b}{1-b}\frac{m_k}{Z_k}\right)^b y_k - \left(\frac{b}{1-b}\frac{1}{Z_k}\right)^b \frac{a(\rho+\mu)\, Z_k + a\mu Z_{-k}}{\rho(\rho+2\mu)} y_k^b \\
&\equiv A_k y_k - B_k y_k^b
\end{aligned}$$

and the coefficients A_k and B_k are positive. Differentiating y with respect to time yields

$$\begin{aligned} \left.\frac{dy_k}{dt}\right|_{z_t=Z_k} &= \rho \left.\frac{dx_k}{dt}\right|_{z_t=Z_k} + \mu\left(\left.\frac{dx_k}{dt}\right|_{z_t=Z_k} - \left.\frac{dx_{-k}}{dt}\right|_{z_t=Z_k}\right) \\ &= \rho\left[A_k y_k - B_k y_k^b\right] + \mu\left(\left.\frac{dx_k}{dt}\right|_{z_t=Z_k} - \left.\frac{dx_{-k}}{dt}\right|_{z_t=Z_k}\right) \end{aligned}$$

Note that except for the last term, the dynamics of y_k are similar to those as for x_k in the case where z_t is constant. In that case, we already established that y hits 0 in finite time. Turning to the additional component, we have

$$\left.\frac{dx_k}{dt}\right|_{z_t=Z_k} - \left.\frac{dx_{-k}}{dt}\right|_{z_t=Z_k} = \left(\frac{dx_k}{ds} - \frac{dx_{-k}}{ds}\right)\cdot\left.\frac{ds}{dt}\right|_{z_t=Z_k}$$

Applying Proposition 3, we know that as $s \to \overline{s}$,

$$\frac{dx_1/ds}{dx_0/ds} \to \frac{(\rho+\mu)\,Z_1 + \mu Z_0}{(\rho+\mu)\,Z_0 + \mu Z_1} > 1$$

Hence, there exists an $\varepsilon > 0$ such that if $s < \overline{s} - \varepsilon$, the laws of motion for y when $z = Z_1$ satisfy

$$\left.\frac{dy_1}{dt}\right|_{z_t=Z_1} < \rho\left[A_1 y_1 - B_1 y_1^b\right]$$

This insures y_1 will hit 0 in finite time, so that if $z_t = Z_1$ for all t, $\overline{s}$ is reached in finite time.

To insure y_0 also hits 0 in finite time, we note that

$$\begin{aligned} \frac{dx_k/dt|_{z_t=Z_k}}{dx_k/dt|_{z_t=Z_{-k}}} &= \frac{ds_k/dt|_{z_t=Z_k}}{ds_k/dt|_{z_t=Z_{-k}}} \\ &= \left[\frac{Z_{-k}}{Z_k}\frac{(\rho+\mu)\,x_k(s) - \mu x_{-k}(s)}{(\rho+\mu)\,x_k(s) - \mu x_{-k}(s)}\right]^b \end{aligned}$$

and so

$$\lim_{s\to\overline{s}} \frac{dx_k/dt|_{z_t=Z_k}}{dx_k/dt|_{z_t=Z_{-k}}} \to \left[\frac{Z_{-k}}{Z_k}\frac{Z_k}{Z_{-k}}\right]^b = 1$$

Suppose that when $z_t = Z_0$ for all t, the individual does not reach $\overline{s}$ in finite time. Then it must be the case that as $s \to \overline{s}$, $x_k \to 0$ more rapidly when $z_t = Z_1$, since we just established x_k does hit 0 in finite time when $z_t = Z_1$. But this would imply

$$\lim_{s\to\overline{s}} \frac{dx_k/dt|_{z_t=Z_1}}{dx_k/dt|_{z_t=Z_0}} > 1$$

which is a contradiction.

Finally, consider two individuals i and j where $a_i > a_j$. Since $s_{it} > s_{jt}$ as long as $s_0 < s_{it} < \overline{s}$, it follows that i reaches $\overline{s}$ before j. At this point, wage inequality is clearly decreasing, since

$$\left.\frac{d}{dt}\left(\frac{w_i}{w_j}\right)\right|_{z_t=Z_k} = \left.\frac{d}{dt}\left(\frac{\overline{s}}{s_j}\right)\right|_{z_t=Z_k} < 0$$

By continuity, there exists an $\varepsilon > 0$ such that both derivatives are negative whenever $s_{it} < \overline{s} - \varepsilon$, which establishes the proof. The final part of the Proposition follows as a corollary to Proposition 3. ■

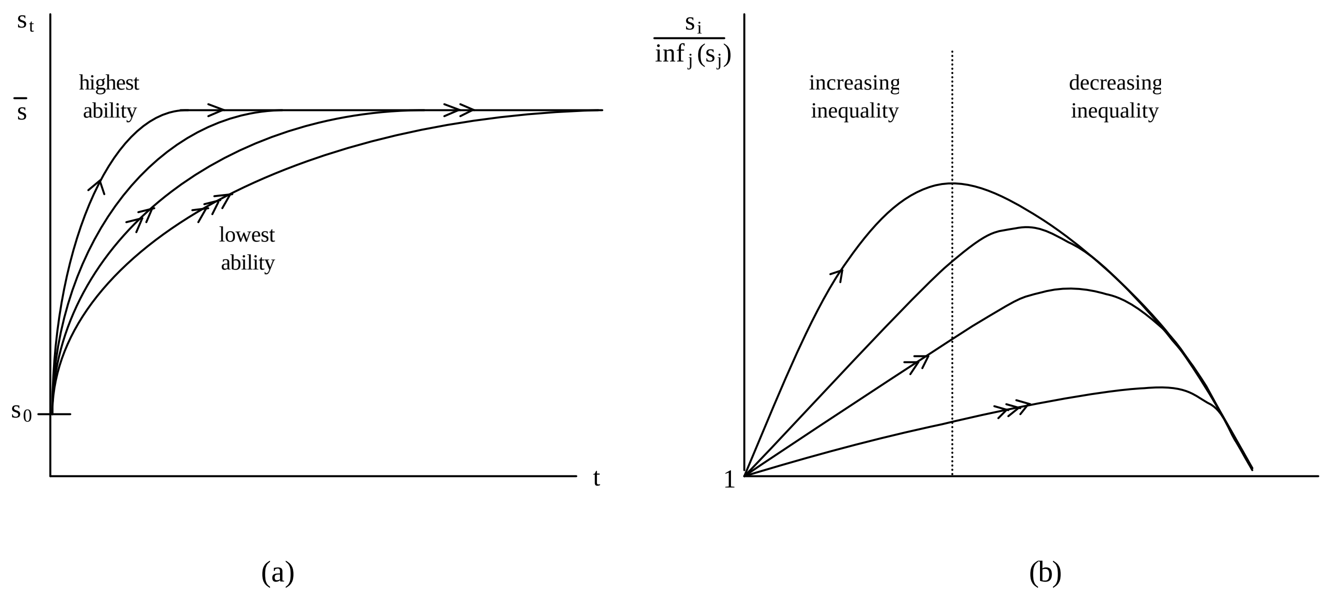

Figure 1: Skill Levels and Ratios with Bounded Skills

Note: Each path in panel (a) represents the evolution of skills for an individual at a given percentile in the distribution of the ability to learn parameter a. Each path in panel (b) represents the ratio of skill between a given percentile in the ability distribution and the skill level of the least able individual in the population.

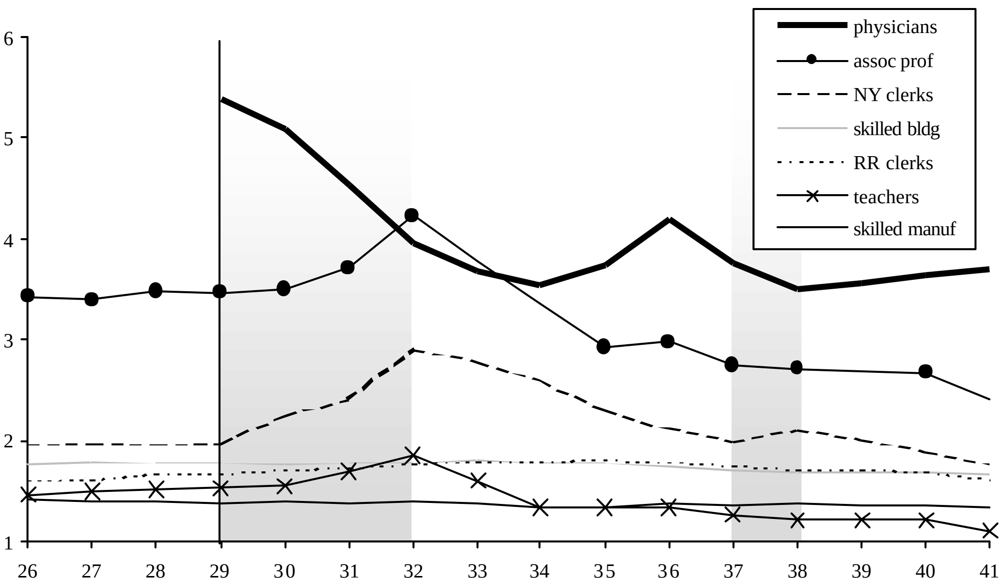

Figure 2: Relative Wages during the Great Depression

Notes: The wage series for public school teachers, associate professors, self-employed physicians, and skilled workers in building trades are series (8), (10), (11), and (13) respectively in Willimason and Lindert (1980). The first three series compare the annual income of teachers, professors, and physicians with 2000 hours of work at the hourly wage rate of unskilled workers based primarily on data reported by the National Industrial Conference Board (NICB). The series for skilled workers in building are hourly wages of skilled workers relative to the hourly wage rates of journeymen, helpers, and laborers in the building trades for various cities. The series on skilled wokrers in manufacturing, clerks in the railroad industry, and clerks in New York State are columns (1), (4.2), and (6) respectively from Table VII of Goldin and Margo (1992). The wages of skilled manufacturing and clerks in New York are expressed relative to the unkilled NICB wages, although the first series is based on hourly wage rates while the latter is based on weekly wage rates. The series on clerks in the railroad industry denote hourly wages of clerks relative to machinists and laborers.

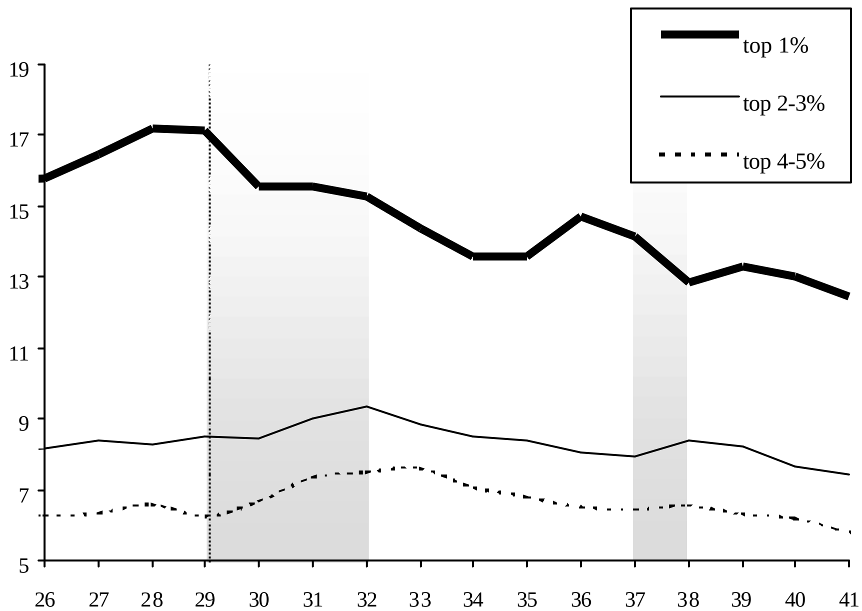

Figure 3: Income Shares of Top Taxpayers during the Great Depression

Notes: Each figure denotes the percentage of national income in each year that belonged to the top x% of the population. The data are taken from Table 122 in Kuznets (1953).

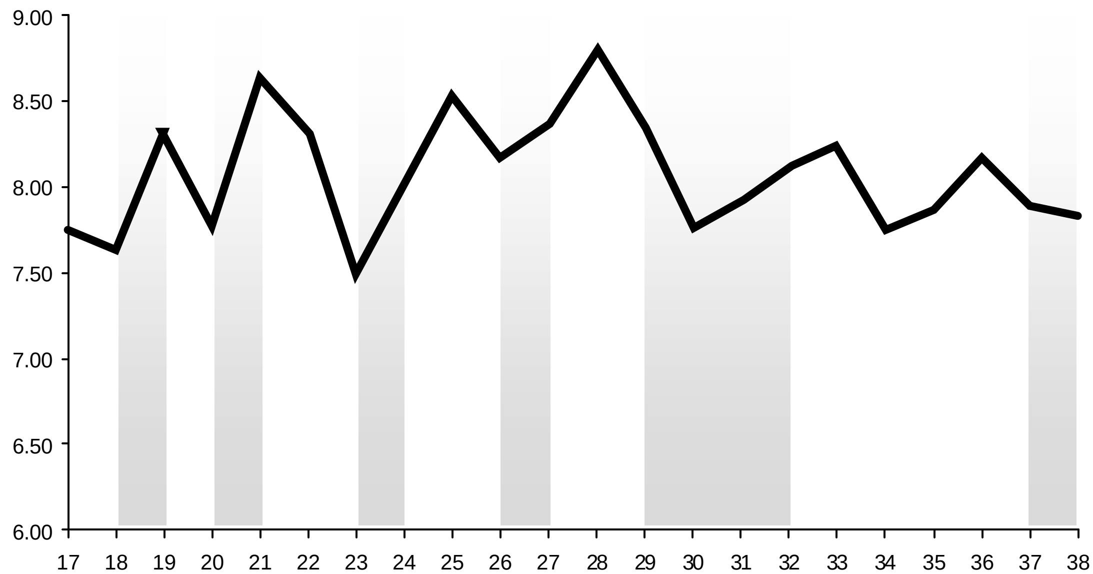

Figure 4: Share of Service Income (Compensation and Entrepreneurial Income) of Top 1% of Economic Income Recipients

Notes: Shaded regions correspond to contractions as identified by Kuznets (1953). The data are based on Table 123 of Kuznets.

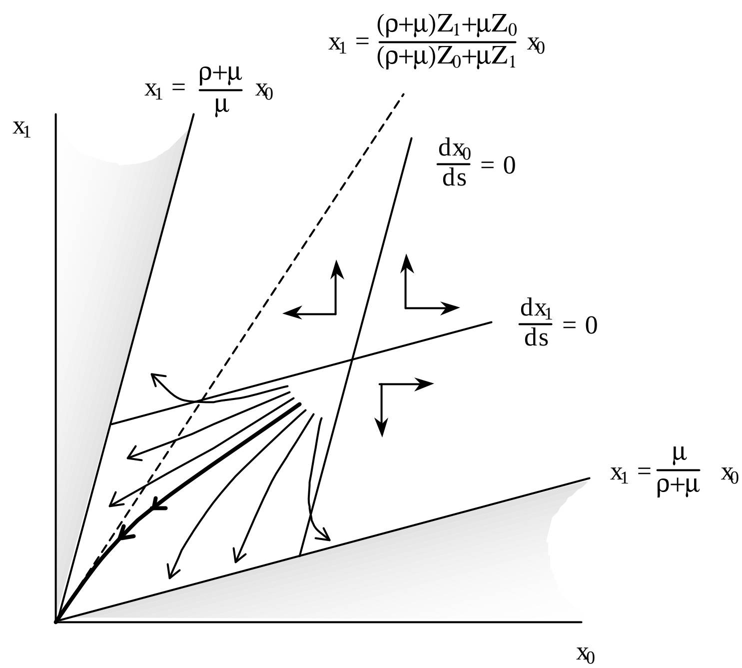

Figure A1: Phase diagram for system with aggregate productivity shocks

Table 1: Change per Year in Shares of Upper Income Groups,
ranked by Economic Income

year	cycle	top 1%	top 5%
1918-19	contraction	0.27	0.44
1919-20	expansion	-0.50	-0.84
1920-21	contraction	1.16	3.40
1921-23	expansion	-0.61	-1.29
1923-24	contraction	0.63	1.40
1924-26	expansion	0.51	0.48
1926-27	contraction	0.46	0.72
1927-29	expansion	0.05	0.06
1929-32	contraction	**-0.53**	-0.03
1932-37	expansion	0.02	-0.38
1937-38	contraction	**-1.46**	**-1.13**
1938-44	expansion	-0.48	-1.02

Source: Kuznets (1953), Table 15

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