Misallocation and Productivity during the Great Depression

Nicolas L. Ziebarth
Northwestern University

October 28, 2011

Abstract

Aggregate productivity fell by 18% between 1929 and 1933. Existing explanations for this decline have focused on unobserved shifts in factor inputs such as labor hoarding. I develop a new hypothesis that focuses on the role of resource misallocation between heterogeneous firms. Using a novel plant-level dataset, I study two industries: manufactured ice and cement. I decompose the overall change in industry-level productivity into efficient productivity shifts and misallocation as in Hsieh and Klenow (2009). Changes in misallocation over the same period of time explain a sizable fraction of around 10 to 15% for cement. I estimate that increases in misallocation can explain 50% of the total decline in industry productivity for manufactured ice between 1929 and 1935. In order to explain these findings, I develop a model of financial frictions that relates misallocation to dispersion in working capital interest rates. If banks are unwilling to take on additional leverage to fund the most productive firms, credit becomes misallocated resulting in factor misallocation and lower aggregate productivity. My model therefore explains the empirically observed increase in misallocation through an increase in the marginal cost of leverage. I argue that these empirical and theoretical results provide another role for the non-monetary effects of the banking crisis during the Depression (Bernanke, 1983a): the collapse of aggregate productivity.

1 Introduction

Why did productivity decline so much during the Great Depression? Measured aggregate TFP fell by 18% from 1929 to 1933 before beginning to recover in 1935 (See Figure 1). Amaral and MacGee (2002) find a decline closer to 20% when the government and agricultural sectors are ignored. Ohanian (2001) estimates that only 1/3 of the fall can be explained by factors such as capacity utilization, factor input quality, labor composition, labor hoarding, and increasing returns 

*E-mail: nlz@u.northwestern.edu. I thank my dissertation committee members: Joel Mokyr, Jonathan Parker, and Joe Ferrie for detailed comments and for funding part of the data collection. I also received useful feedback from Bob Gordon, Paul Grieco, Josh Hausman, Matthias Kehrig, Ryan Marsh, Giorgio Primiceri, Chris Vickers, Thijs van Rens, and participants at the Northwestern Macro Lunch, Economic History seminar, EHA Annual Meeting, and the NBER Summer Institute DAE. Other portions of the data collection were funded by the Graduate School and the Center for the Study of Industrial Organization. William Creech at the National Archives provided useful information on the data. Stephen Karlson kindly provided some data on the cement industry. Mary Hansen helped organize data collection at the National Archives. Doug Bojack and Joanna Gregson did yeoman’s work photographing the original schedules. Dan Thomas was absolutely indispensable. I also thank the Robert Eisner Memorial Fellowship as well as the Sokoloff Fellowship for providing support.
The decline in productivity is even more striking when put in the context of the major innovations being made at this time. To the point, Field (2011) has argued that the Depression was actually a “great leap forward” for the U.S. economy. Bernstein (1987) also documented a number of process innovations in a variety industries made around the same time. These inventions and innovations included Teflon in petrochemicals industries and such household items as the radio and refrigerator. These innovations made during the depths of the Depression along with the expansion of the transportation network laid the groundwork for the economic miracle of WWII and the post-war boom. These breakthroughs should have had a positive impact on productivity all else equal. This makes the decline that much more striking and puzzling.\(^2\)

This feature of the Depression is not unique to the U.S. experience. Calvo et al. (2006) find in a broad set of emerging market crises that output collapses and recoveries are associated with collapses in TFP much like the U.S. Great Depression. In an even broader set of depressions not just those associated with sudden stops, a similar pattern of sharp productivity declines emerges (Kehoe and Prescott, 2002). In addition to these declines in TFP and output, usually there is an associated deterioration in credit market conditions. What these papers all highlight though is that in an accounting sense, understanding depressions is closely tied to understanding the dynamics of aggregate productivity.

This paper makes two contributions to understanding the evolution of productivity during the Great Depression. First in an accounting sense, an increase in the misallocation of resources across production units explains a large fraction of the overall decline. Second, there is theoretical and empirical evidence to believe that this increase in misallocation is driven by the banking crisis and, in particular, the collapse in interbank lending between 1929 and 1933.

First, to measure misallocation, I build on the methodology used in both the growth (Hsieh and Klenow, 2009) (HK) and business cycle (Chari et al., 2007) literatures that measures deviations from a neoclassical benchmark.\(^3\) The crucial distinction necessary for measuring misallocation is

---

1. In a paper very similar to Chari et al. (2002), Weder (2006) finds that a RBC type model with modest amount of increasing returns to scale can successfully matches the changes in investment, employment, and output, but severely underestimates the decline in productivity over the first years of the Depression.
2. The seeming disconnect between Field (2011) and Ohanian (2001) is more apparent than real since the time periods they study are slightly asynchronous. Field studies the whole decade of the 1930s while Ohanian focuses on the first half of the 1930s and in fact, notes the remarkably strong productivity growth after 1933.
3. At the same time, these two strands of the literature have conceptualized them in very different ways. For example, in the business cycle literature, Chari et al. (2002) argue that a “wedge” between the marginal rate of substitution and the real wage during the Great Depression can explain the collapse in employment. In the growth literature, however, Chari et al. (2002) argue that the decline in productivity is driven by the banking crisis and, in particular, the collapse in interbank lending between 1929 and 1933.
the difference between physical productivity $TFP_Q$ and revenue productivity $TFP_R$, which by definition is equal to $TFP_Q \times p$, where $p$ is the price a firm charges. The difference is in the units productivity is measured in. The first is in terms of raw output, the second in terms of dollars. An efficient allocation of resources along the intensive margin taking as given the distribution of $TFP_Q$ will equalize $TFP_R$ across heterogeneous plants. Therefore, differences in $TFP_R$ across plants can be interpreted as a misallocation of resources.\footnote{I do not specify whether these differences are related to so-called output, labor, or materials wedges.} In addition to the dispersion in $TFP_R$, there are other dimensions of misallocation. For one, I consider the correlation between $TFP_R$ and $TFP_Q$. Restuccia and Rogerson (2008) emphasize this correlation as particularly deleterious for productivity since when the correlation is positive, the most physically productive firms are also the most constrained. In a calibrated model similar in spirit to HK, they show that i.i.d. dispersion in $TFP_R$ across firms does not lead to large losses in productive efficiency, but a strong positive correlation does.

To estimate the empirical relevance of misallocation, I build a novel plant-level dataset from the Census of Manufactures taken in 1929, 1931, 1933 and 1935 of two industries: manufactured ice and cement.\footnote{I am currently collecting data on a number of other industries including timber and agricultural implements to extend the analysis.} These industries have a number of convenient features. First, their products are homogeneous making price and productivity comparisons valid. Second, because I observe a good measure of a plant’s capital stock and physical output, I can estimate plant productivity directly. This is important because HK, who do not have output measures, have to lean heavily on a particular demand structure to infer physical output from revenue. Depending on the assumed elasticity of substitution between varieties, for cement, changes in misallocation are important for changes in productivity, explaining between 10 and 20\% for 1935. Misallocation also plays an important role for productivity dynamics in the intervening years of 1931 and 1933. I find that changes in misallocation can explain between approximately 40 and 60\% of the overall decline in industry productivity for the manufactured ice industry between 1929 and 1935. Both measures of misallocation, the dispersion of $TFP_R$ and the correlation between $TFP_R$ and $TFP_Q$, show sharp increases over this time period.\footnote{These patterns regarding dispersion and correlation are also present in another industry that I have collected, the macaroni industry. Results here are only for labor productivity since the data lack a capital measure.}
My estimates are almost surely a lower bound on the overall effect of misallocation on productivity during the Great Depression since I ignore two potentially large sources of misallocation. First, I do not consider misallocation on the extensive margin of plant entry and exit. Though the empirical results will take into account changes in the distribution of physical productivities across plants, all of those changes will be thought of as efficient. Second, the result will ignore a potentially large source of misallocation between industries. If the average productivity between industries changes, resources should flow from unproductive to productive industries. This is a dimension stressed by Bernstein (1987) for the Depression period. Unfortunately, I am unable to address it with my currently limited set of industries.

I stress the role of financial frictions in rationalizing these changes in misallocation and their effects on productivity. Not surprisingly, the literature on the role of financial frictions on business cycles has been strongly influenced by the experience of the Depression. The classic work of Friedman and Schwartz (1971) argued the banking crisis played a major causal role in the collapse of the real economy. However, they assigned a purely monetary role to the wave of bank failures between 1929 and 1933. The work of Bernanke (1983b) was the first to argue that the effect of bank failures was not solely felt through a decline in the money supply but also in more direct ways. In particular, he stressed shifts on the supply side stemming from a loss of informational capital embodied in banks.

Three empirical observations motivate this theoretical focus on financial frictions. First, I find that there is a positive correlation between TFPR and state-level borrowing rates collected by Bodenhorn (1995). This shows that dispersion in lending rates can drive dispersion in TFPR. In turn, I document that the dispersion of state-level lending rates shows a sharp increase between 1929 and 1933 followed by a decline of similar alacrity from 1933 to 1935. This timing exactly matches the changes in productivity and misallocation. At a time of more or less unit banking, what is crucial for moderating regional differences in interest rates is the interbank market. So the third observation reemphasizes the well known fact that interbank markets collapse between 1929 and 1933. Taken together, these facts show the causal chain from banking to real outcomes I attempt to capture in my model.

In my model, banks face a cost of taking on more leverage, which generates an endogenous

---

7 An extension of the model I develop endogenizes the dispersion in physical productivity in plants.
balance sheet effect. I motivate this sort of friction through an adverse selection problem in the interbank market (Kurlat, 2011). The interbank market treats banks with large funding needs skeptically because of worries that the bank is trying to sell lemons. Because of this, these banks face a higher cost of funds, or equivalently, banks \textit{ex ante} face a strictly convex cost of taking on leverage. Banks fund working capital loans to firms who have to borrow upfront to purchase inputs. In an efficient allocation of resources, the distribution of bank leverage ratios should “match” the distribution of firm productivities. Banks with good opportunities should be highly leveraged and those without opportunities should fund the borrowing of the good banks. The friction that limits bank leverage leads to differences in working capital interest rates and, hence, limits the amount of reallocation from unproductive to productive firms. This in turn generates dispersion in $TFPR$, dispersion in working capital interest rates, a positive correlation between $TFPR$ and $TFPQ$, and an inefficiently low level of productivity.

The shock that I emphasize is one to the marginal cost of leverage stemming from an increase in the adverse selection problem.\footnote{Leverage can be thought of as total assets divided by equity. More precisely for the commercial banks I focus on, leverage is assets divided by equity plus deposits.} When adverse selection problems worsen, the convexity in the leverage cost function increases. This leads resources to become stuck in areas where demand is relatively low or with firms that are relatively physically unproductive. The shock, in turn, leads to a flattening of the distribution of leverage ratios across banks. In addition, dispersion in working capital interest rates rises thereby increasing dispersion in $TFPR$. Moreover, the correlation between $TFPR$ and $TFPQ$ increases as the higher cost of leverage falls most severely on the most productive firms. This generates an endogenous decline in productivity. Note that this mechanism does not emphasize changes in the \textit{overall} leverage ratio of the financial sector nor the amount of bank capital \textit{per se}. These actually have no effect on dispersion and productivity. Instead the relevant summary statistic for the health of the banking sector as it affects productivity is the dispersion of leverage ratios across financial firms and firm borrowing rates echoing Gilchrist and Zakrajsek (2011).\footnote{Though this latter measure does not summarize the correlation between the rates and the productivity of the firms that pay them.}

I present a variety of empirical evidence to support the theoretical implications of my model. One piece of evidence comes from aggregate banking data. Figure 2 displays the dynamics of lever-
age, capital, and the standard deviation of leverage from state-level data on all banks normalized
to their 1926 value.\(^\text{10}\) In line with my theory, the changes in the standard deviation of leverage
ratios across states very closely match those for aggregate productivity. It declines sharply starting
in 1929 and then recovers quickly starting around 1933. Other measures such as total bank capital
or the overall leverage ratio of the banking sector do not correlate with the changes in productivity.

Besides this testable implication based on banking data, my theory also predicts that during
the time when the interbank markets are shut down, real outcomes should be more closely related
to local banking variables. I offer evidence that state-level banking leverage is positively correlated
with \(TFPR\) during the crisis years but is uncorrelated in the others. As a second piece of cross-
sectional support, I find that regional dummies explain more of the variation in \(TFPR\) in 1931
relative to 1929 and 1935. A slightly more oblique test, it has the feature that it does not require
me to specify what the correct measure of local banking is. A final piece of evidence comes from a
comparison to the Canadian experience during the Depression. The declines in output were very
similar in both countries, but the fall in productivity is much less severe in Canada. A crucial
difference between the depressions in these countries is that there is no banking crisis in Canada.
Furthermore, the Canadian banking system had extensive branching, insulating resource flows from
the vagaries of interbank markets.

The focus of my model is quite distinct from the classic work by Bernanke (1983b) and almost all
subsequent work on financial frictions. The papers in this literature have tended to focus on the role
played by banks in funding long-term investments (and potentially consumer durable purchases).
The central insight of these models was that small changes in the level of bank capital could have
large effects on investment through constraints on leverage due to limited commitment and moral
hazard problems. This view of how financial frictions matter has led people to solely focus on
anomalous moves in investment as evidence for financial frictions. For example, Carlstrom and
Fuerst (1997) show that the classic financial frictions model of Bernanke and Gertler (1989) can be
written as the standard neoclassical growth model with a time-varying wedge in the household’s
investment decision. In that model, there is no impact of financial frictions on productivity.

This irrelevance of financial frictions for anything but investment has been taken to the extreme

\(^{10}\) The data is taken from Comptroller of the Currency (1937). This is the finest level of disaggregation for compre-
hensive bank data that exists.
by Chari et al. (2007). They argue that since the neoclassical growth model can rationalize the fall in investment during the Depression, financial frictions and the banking collapse did not matter for the Depression. My paper shows that this conclusion is too hastily drawn. In conjunction with the theoretical work of Kurlat (2011) and Buera and Moll (2011), my results highlight another role for the non-monetary effects of the banking crisis during the Depression: the decline in aggregate productivity.\footnote{Sandleris and Wright (2010), studying the crisis in Argentina, attempt a similar exercise. They quantify the loss on TFP from greater misallocation across and between sectors at 10\%.
}

The paper proceeds as follows. The next section lays out the accounting framework that I employ in measuring the contribution of misallocation to productivity changes. Section 3 discusses the data source and the industries that I study. I then discuss the empirical implementation in section 4. Section 5 reports the empirical impact of misallocation. Then I build a model and calibrate it in section 6 to explain these patterns. Section 7 offers some evidence for predictions of that model. I conclude in section 8. Appendices collect some robustness checks for the empirical results and various extensions of the model.

\section{An Accounting Framework}

To estimate the role of misallocation on industry productivity, I build on the accounting framework of HK. Industry output is a Dixit-Stiglitz aggregator of differentiated output from $N$ firms\footnote{In this section, I will refer to firms not plants for ease of exposition, but keep in mind that the data is at the plant-level.} in the industry:\footnote{As HK show, it is trivial to extend this model to a number of different industries with no complication. As I note below, what is interesting about this broader case is how average levels of distortion within an industry distort resources \textit{between} industries.}

$$Y = \left( \frac{1}{\psi} \sum_{i=1}^{N} Y_i^{\psi - 1} \right)^{\frac{1}{\psi - 1}}$$

Firm $i$ operates a constant returns to scale production function.\footnote{It is also possible to posit a decreasing returns to scale production function a la Lucas’ span of control setup used in Restuccia and Rogerson (2008) and Sandleris and Wright (2010) and dispense with the differentiated products setup. The inverse of the returns to scale parameter would play a similar role to $\psi$ in my setting.}

$$Y_i = A_i L_i^{\gamma_L} M_i^{\gamma_M} K_i^{1-\gamma_L-\gamma_M}$$
I include materials and energy $M_i$ as a third factor of production for consistency with my empirical work. The firm solves

$$\max_{L_i,K_i,M_i} p_i Y_i - (1 + \tau_i)(wL_i - rK_i - p M_i)$$

subject to its demand curve. The term $\tau_i$ is a “wedge” that distorts the outcome from the efficient one. One can think of it as an abstract tax that increases the costs of a firm’s inputs. For exposition, I consider the case with only one wedge. It is possible to consider separate wedges on the different factors of production. These different wedges would then distort the firm’s relative choice between, say, capital and labor. The wedge I consider simply affects the scale of operations.

This wedge is taken as given from the point of the view of the firm. HK and others such as Restuccia and Rogerson (2008) think of these wedges as generated by government policies that restrict entry or favor certain enterprises, say. For now, I remain agnostic on where the wedges come from and prefer that they be thought of as purely an accounting device. Eventually I will offer evidence that the wedge is driven in part by working capital interest rates. My model will emphasize differences in these borrowing rates as a key source of misallocation during the Depression.

HK building on Foster et al. (2008) stress the difference between $TFPR_i$, which is productivity in terms of revenue and $A_i$, which is physical productivity (also known as $TFPQ$). The two are linked by the identity

$$TFPR_i = p_i A_i$$

With this demand structure, the only reason $TFPR$ should vary across plants is due to wedges.\footnote{Note that I could just as well interpret differences across firms in terms of relative demand shocks instead of physical productivity. Assume instead that final output is given by}

$$Y = \left( \sum_{i=1}^{N} (Z_i Y_i)^{\frac{\varphi-1}{\varphi}} \right)^{\frac{\varphi}{\varphi-1}}$$

where $Z_i$ can be interpreted as a demand shock for variety $i$. This setup will be isomorphic to my model with differences in productivity $A_i$ across firms.
advantage by charge lower prices thereby leaving fixed TFPR. In particular,

\[ TFPR_i \propto 1 + \tau_i \]

To emphasize, I am solely interested in dispersion in TFPR since it is the relevant statistic for productivity losses. This is why I study the single wedge case here. That being said, it is potentially important to consider more wedges as way to to identify the fundamental source of misallocation. Dispersion in TFPR driven by labor wedges points to possibly a very different source than dispersion driven by capital wedges.

Now let \( L = \sum_i L_i, M = \sum_i M_i, K = \sum_i K_i \). Then it is straightforward to show that measured industry TFP is given by

\[ TFP = \frac{Y}{L^{\gamma_L} M^{\gamma_M} K^{1-\gamma_L-\gamma_M}} = \left[ \sum_{i=1}^{N} \left( A_i \frac{TFPR}{TFPR_i} \right)^{\psi-1} \right]^{\frac{1}{\psi-1}} \tag{1} \]

where \( TFPR \) is the geometric mean of firm-level TFPR given by

\[ TFPR = \frac{\psi}{\psi-1} \left[ \frac{R}{(1-\gamma_L-\gamma_M) \sum_i \frac{1}{1+\tau_i} \frac{P_i Y_i}{P Y}} \right]^{1-\gamma_L-\gamma_M} \left[ \frac{p_M}{\gamma_M \sum_i \frac{1}{1+\tau_i} \frac{P_i Y_i}{P Y}} \right]^{\gamma_M} \left[ \frac{w}{\gamma_L \sum_i \frac{1}{1+\tau_i} \frac{P_i Y_i}{P Y}} \right]^{\gamma_L} \]

I will think separately about two key sources of efficiency losses: changes in the variance of TFPR and the correlation between TFPR and TFPQ.

To understand how they impact overall productivity, it is useful to develop a particular version of equation 1.

**Proposition 2.1** Assume that \( N \) is large. In addition, assume that \( A_i, TFPR_i \) are jointly log normal with means \( \log A, \mu_R \), variances \( \sigma_A^2, \sigma_R^2 \) and correlation \( \rho_{QR} \), then

\[ \log TFP = \log TFP^* - \frac{\psi}{2} \sigma_R^2 - (\psi - 1) \rho_{QR} \sigma_A \sigma_R \tag{2} \]

where \( \log TFP^* = \left[ EA_i^{\psi-1} \right]^{\frac{1}{\psi-1}} \).

Equation 2 provides a straightforward decomposition of changes in productivity into changes in
measures of misallocation.\textsuperscript{16} The first term \( \log TFP^* \) can be thought of as the efficient level of industry TFP taking as given the distribution of plant physical productivities.

To build intuition, the first term can further be written as

\[
\left[ \mathbb{E} A_t^{\psi-1} \right]^{\frac{1}{\psi-1}} = \log A + \frac{\psi - 1}{2} \sigma_A^2
\]

Here \( \log A \) captures a “pure” technology shock that affects the mean of the productivity distribution. In reality, \( \log A \) can also capture changes in the average firm productivity due to say labor hoarding. It will also capture any “cleansing effects” on the extensive margin of the Depression whereby the least physically productive firms are driven out (Caballero and Hammour, 1994). This selection process will also presumably have effects on \( \sigma_A \). My measure of the efficient level of productivity will incorporate all of these changes along the extensive margin. In the context of the model though, I will only focus on misallocation along the intensive margin treating the distribution of physical productivities as exogenous.

The comparative static for \( \sigma_A \) is on the face of it counterintuitive. Why should a more dispersed distribution of productivities increase overall productivity? The key to understanding this is to remember that industry TFP is \textit{not the arithmetic mean but a generalized geometric mean} of the plant-level physical productivities. The generalized geometric mean is not invariant to arithmetic mean preserving spreads. In fact, because \( \psi > 1 \), the generalized mean upweights high productivity firms relative to low productivity ones. So a geometric mean preserving spread in the distribution of firm productivities increases industry-level productivity. The term \( \sigma_R \) works in exactly the opposite way as any variation in \( TFPR \) about the industry mean is a loss in efficiency as emphasized by HK.\textsuperscript{17} Finally, the term \( \rho_{QR} \sigma_A \sigma_R \) is the dimension of misallocation stressed by Restuccia and Rogerson (2008). A higher correlation leads to greater efficiency losses all else equal because more productive firms face higher wedges on average.

It may seem that this particular approach to measuring misallocation is very dependent on the

\textsuperscript{16}It is useful to step back and compare this to other decompositions in the literature, e.g. Foster et al. (2008); Petrin et al. (2011). Those works have all written down accounting identities that decompose changes in productivity into broadly speaking within-firm changes and between-firm changes. The main interest there was in quantifying which of these terms dominated. While worthy exercises, those papers were not able to address the question of in what sense these shifts can be thought of as efficient since they all lacked a benchmark model.

\textsuperscript{17}Though do note that a 1% increase in \( TFPR \) does not necessarily have the same magnitude of an effect as 1% decrease in \( TFPQ \) since they are multiplied by different coefficients.
CES demand structure. What if for example the true pricing model was a limit pricing model where the most productive firm charged a price just below what the second most productive firm charges? Then to what extent are my results still valid? First, I want to argue that possible worries about misspecification of the pricing structure are a much larger concern for HK. Then I want to suggest that differences in TFPR are still evidence for misallocation and the formula of industry TFP derived in equation 1 is more general than it appears.

The pricing structure plays a dual role for HK. First, they use their demand model to aggregate plant-level productivities into an industry TFP. Second, they also use the demand structure to infer physical productivity of each individual plant. In their data, they do not observe physical output. Instead with an assumed value of \( \psi \), they invert revenue to back out physical output and then measure TFPQ. It is clear that in the limiting pricing example, the method HK use could go horribly wrong. If the most productive firm is charging a price that only depends the productivity on the next most productive firm, then the inferred level of TFPQ from TFPR should have nothing to do with the true TFPQ except that it provides a lower bound on the true value. All that matters for how prices are determined in this example is that the market leader is more productive not how much more productive. As I discuss below, I have direct measures of physical output so I do not need to rely on the demand structure. Therefore, misspecification in the pricing structure does not affect my physical productivity estimates. The obvious question then is why assume this demand structure at all if it is not necessary to back out physical productivity from revenue productivity.

The answer to this question is the demand structure provides particularly clean expressions besides, being standard in the macroeconomics literature. Moreover, it is important to emphasize that even under the limit pricing case, there are gains in productivity to be had if resources were reallocated from low to high TFPR plants. If a social planner operated both the final technology and all of the intermediate firms, the planner would choose optimally to equalize TFPR taking as given the distribution of TFPQ. This is the sense in which dispersion in TFPR is generically a sign of misallocation. The question is how those efficiency losses are translated into aggregate industry productivity. Returning again to the limit pricing case, clearly it will not be possible to aggregate along similar lines since \( \psi \) has no meaning in terms of pricing in this case. Still the social planner logic suggests that we can always define industry productivity relative to the efficient level where TFPR is equalized across all plants. In this sense, equation 1 can be thought of more generally
than the CES case I consider. It is simply necessary in this more general setting to no longer treat \( \psi \) as a structural parameter, but rather as a reduced form parameter that is an amalgam of not only demand factors but some potentially non-constant function of the true pricing structure. This is the sense in which the formulation is more general here though it comes at the cost of stripping \( \psi \) of much meaning.

One final note is that this model only features within industry misallocation and not between industry misallocation nor between sector misallocation. This will parallel my empirical work which will just focus on within industry misallocation. With data for a broader set of industries, it is trivial to extend this model to study aggregate productivity. Note that while the overall mean level of \( TFPR, \mu_R \), does not affect a given industry’s TFP, it does in fact impact the industry’s output. Industries that face higher than average mean \( TFPR \) receive lower levels of resources in the form of a smaller total workforce and less capital. So in an aggregate model with many different industries, variation in industry level \( TFPR \) would lead to losses in aggregate TFP as well. On the other hand, Sandleris and Wright (2010) has found that most of the misallocation is within industries or sectors rather than between. Still others such as Bernstein (1987) have argued that for the Depression, much of the misallocation is between industries rather than within.

3 Data

The data used for this paper come from the Census of Manufactures (CoM) collected by the Census Bureau in one form or another since 1810. Yet after the 1880 Census, there has been little work done with plant-level returns from the CoM. The reason for this is that it had been assumed that the underlying schedules for the intervening years were destroyed. The 1890 population schedules along with the manufacturing schedules were lost to a fire.\(^\text{18}\) The other years of the Census of Manufactures through 1950 were destroyed by an act of Congress in order to conserve space at the National Archives. To this day, there are no regular procedures in place to preserve the underlying schedules once tabulations have been made (Nucci, 1998). The Bureau of Economic Analysis has an ongoing large scale project to link the schedules from 1950 onwards (Nucci, 1998). This modern data has been used in a number of studies on a variety of different topics, e.g. Davis and Haltiwanger

\(^{18}\) The story is a bit more complicated with only about 25% of the schedules totally destroyed. The other 75% were lost due to bureaucratic neglect.

For reasons unknown, the schedules for 1929, 1931, 1933, and 1935, the first half of the Great Depression, were kept and are housed at the National Archives. Over these 4 censuses, there are close to 750,000 schedules with a wide variety of questions. These include revenue broken down by price (unit value) and quantity, total wage bill, cost of intermediate goods, and number of wage earners employed at a monthly frequency. There is other information about whether the plant is incorporated (if unincorporated, who the owner is) and whether the plant has moved or changed names in the last year. A major limitation of the data is that there are no specific questions about assets or liabilities. The modern census and even its 19th century counterpart have a question about the value of capital invested. However, for the Depression censuses, there are only questions related to the specific type of capital employed in a given industry. For example, bakery firms are asked the number of bread slicing machines and ovens. An example of the front page of a schedule is in Figure 3.

An important question when working with this data is coverage. Raff (1998) argues the coverage is quite good. In my experience, I have discovered some missing schedules most likely related to misplacement by the Archives. For example, returns for the ice industry in 1931 in Texas seem to be missing. The bigger question is how the Census was conducted. The 1931 Census had to be organized on a tight schedule with a limited budget. The 1933 Census was a work relief project. It is not improbable that plants were missed. In other work (Chicu and Ziebarth, 2011), I have compared the Census records to other sources for the cement industry. In that work, we cross-checked not only the numbers from the schedules to other independent sources but to the published Census tables themselves. The tabulations from the schedules lined up remarkably well. First, it appears that at least for the cement industry, all of the schedules that the Census tabulated in creating the published tables are at the Archives. Second, in comparison to independent trade publication sources on revenue and physical output, the Census values differ by only plus or minus a few percent in any given year. Of course, cement is an industry that should be measured well by

---

19 There can be a bit of confusion with the dating of the censuses. The year convention I will use refers to the year the data are meant to cover. The Archives usually employs a convention where the year refers to the year in which the data are collected, which is one year subsequent. For example, the data in the 1929 census cover things that occurred in calendar year 1929, while the data was collected during the calendar year 1930. The Archives is not altogether consistent in how they record the years.

20 For years 1929 and 1935, the schedules are on microfilm while 1931 and 1933 are on paper. These are in Record Group 29, Entries 307, 307-A, 309, 309-A.
the Census. Cement is not a large industry in terms of the number of plants (around 160 plants per year) and all of the plants are quite massive and immobile making them hard to miss. Still I take some encouragement from these considerations.

The plant-level data have been used previously in limited contexts. In Bresnahan and Raff (1991), the authors use data from the motor vehicles industry to examine the evolution of firm heterogeneity over the Depression. They find that differences in production technologies predict whether inefficient plants exit the industry. Bertin et al. (1996) study blast furnaces as another case of the impact of plant-level heterogeneity on industry behavior. Both papers to a certain extent address the question of productivity in their respective industry. However, the focus of each is slightly different. While the first focuses mainly on the extensive margin of entry and exit, the second is mainly an analysis of the sources of short-run increasing returns to labor. Foss (1981) created a representative sample of 9000 firms from 1929 to examine the length of the workweek. Some recent work using the data includes my own work: Ziebarth (2011) and Vickers and Ziebarth (2011). The first studies the effects of the banking crisis that enveloped Mississippi while the latter examines the question of collusion under the National Recovery Administration’s “Codes of Fair Conduct.” To be sure, the published tables—sometimes disaggregated to the county-level—have been used in a number of works. Rosenbloom and Sundstrom (1999) were the first to actually transcribe the tables at the state-industry level before and after the Depression.

3.1 Industry backgrounds

3.1.1 Manufactured ice

The manufactured ice industry consisting of over 5000 plants spread across the country produced an important consumer staple. While refrigerators were growing ever more popular with penetration rates rapidly rising throughout the Depression, the main way people still cooled their perishable goods was through ice boxes stocked with manufactured ice. How ice was manufactured at the time is almost no different than how a modern refrigerator makes ice. There are a few useful features

---

21 The study is in some ways similar to my interest which is on how intra-industry heterogeneity impacts industry productivity. Though our techniques and focus are wildly different.

22 I have been unable to track down any extant copies of this data.

23 Currently, my sample only includes the following states: Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Massachusetts, Michigan, Mississippi, New Mexico, Oklahoma. The images for the remaining states have been collected just not digitized yet.
of the industry. First, the Census in each year asked a question about the capacity of the plant’s compressors, which do the serious work of compressing the coolant. This gives a very good capital stock measure though it does exclude capital in the form of structures and other equipment. Second, the production process is very simple with a minimal number of homogeneous inputs consisting of water, ammonia, and salt. This makes it unlikely that differences in technologies across plants are driving the misallocation results. Third, there is very little product differentiation between the types of ice produced. What is surely the most important source of product differentiation is spatial differentiation.  

3.1.2 Cement

Portland cement, often known by its shorthand as “cement,” was an important industry at the time supplying a crucial input for building structures and roads. The cement industry is a convenient industry to study for several reasons similar to ice. Most important for this work is that the product is essentially homogeneous, so that for a buyer the identity of the plant offering the product is of limited relevance. Another useful feature like ice is that there are numerous relatively isolated markets due to geographical segmentation in the industry. Portland cement is both relatively cheap to produce and particularly heavy. For this reason, shipping costs are a nontrivial component of cement prices, and it is uneconomical to ship cement long distances. Thus, for any given plant, its practical market lies within a relatively short distance – commonly cited to be within 200 miles, and often less. However, unlike ice which is dominated by many small firms, cement markets are usually thought of as oligopolistic with only a few plants in each market.

For this industry’s capital measure, production capacities were transcribed from exhibits that

---

24There are two other minor sources of differentiation. A first source is in the size of the finished product. Can ice was sold to households in smaller portions while plate ice made of large chunks of ice was mainly used in cold storage facilities. This dimension is observed in the data as the Census asks for production totals of each type. In actuality, very few of the firms in my dataset report producing plate ice.

One other dimension of product differentiation is between raw and distilled ice. The original process for making ice required distilled water. By the 1930s, this had been replaced by processes that could produce ice using “raw” or tap water. Very few firms in my sample are actually producing distilled ice for the obvious reason that distilling water is an expensive process. Moreover, when the vast majority of this ice is being used for cooling food or people, it does not really matter what kind of water the ice is made from. An ice box does not know whether or not the ice is made from raw or distilled water. Even if the ice was used to cool drinks, the quality advantage for distilled ice is trivial.

25Dumez and Jeunematre (2000) provide a comprehensive overview of the economic characteristics of the Portland cement industry.

26It is important to keep in mind the distinction between plants and firms for cements. While there are about 160 plants across the country, there are closer to only 10 firms controlling all these plants.
formed a major part of an anti-trust case against the industry in 1941 (Cement Institute v. U.S.).

These capacities have been cross-checked against the Pit and Quarry Handbook, which among other things contains a directory of all cement plants in any given year and has capacities for a subset of the plants. For the cases where capacities were reported in both, the correspondence between the directory and the FTC sources is quite good.

4 Empirical Setup

I calculate \( \log \text{TFPR}, \log \text{TFPQ} \) for the ice and cement industries as

\[
\log \text{TFPQi} = \log y_i - \gamma_L \log L_i - \gamma_M \log M_i - (1 - \gamma_L - \gamma_M) \log K_i
\]

\[
\log \text{TFPRi} = \log p_i y_i - \gamma_L \log L_i - \gamma_M \log M_i - (1 - \gamma_L - \gamma_M) \log K_i
\]

where \( y_i \) is physical output, \( y_i p_i \) is revenue, \( L_i \) is wage earners, \( M_i \) is cost of total materials and energy used, and \( K_i \) is the capital measures discussed above. The term \( M_i \) is meant to at least partially control for differences in capacity utilization through variation in electricity use. The census has an hours worked variable that is unfortunately missing for 1933, which is why I focus on a specification with only number of wage earners as the labor measure.

I follow Basu and Fernald (1997) in specifying the production function in terms of gross output. The question then is how to estimate the production elasticities. There is of course a large literature on estimating production functions e.g., Marschak and Andrews (1944), Griliches (1957), Olley and Pakes (1996), and Levinsohn and Petrin (2003). I employ a cost shares type method. Though a number of caveats apply, variants of this approach have been standard since Solow (1957). The complication relative to the standard case is that I do not observe total costs. So I rely on the fact that costs should be a constant multiple of revenue along with an assumption similar to HK that profits are distributed pro-rata to each of the factors. The assumption about distribution of profits is important. If instead all profits accrued to capital, then my estimates would be biased.

Then \( \gamma_L \) can be calculated as the fraction of total wage bill to revenue, similarly for materials,

\textit{27} Stephen Karlson transcribed these capacities from the originals and graciously shared the data.

\textit{28} I have also experimented with a production function that only includes capital and labor as factors of production and specifies output as real value added where revenue is deflated by a plant’s own price.
and $\gamma_K = 1 - \gamma_L - \gamma_M$ as the residual. To estimate the industry-specific production elasticities, I average across all plants and years. This estimation method will be consistent with my theoretical specification to the extent that the working capital constraint I will impose affects each factor of production equally.

One point to note is that $M_i$ is in nominal terms. There does not appear to exist a suitable price deflator for this variable. A similar issue faces Sandleris and Wright (2010) and they choose to simply not deflate the variable. I make the same assumption so any changes in the price of these inputs will show up as shifts in aggregate productivity. It again is important to emphasize that this will not affect differences in productivity between plants. It will be useful to keep the possible scale of this bias in the overall productivity trends in mind. For reference, the overall price level falls by around 15% from 1929 to 1931 and then by another 7% from 1931 to 1935. Given an estimated materials share of around 1/2 and assuming that the prices of inputs track the general price index, then the growth of both $TFPQ$ and $TFPR$ will be overestimated by 7.5% from 1929 to 1931 and by an additional 3.5% from 1931 to 1935.

Besides lacking a deflator for materials inputs, an additional limitation is that I lack information on non-production workers. In 1929, 1933, and 1935, there is information about salaries paid for non-production workers. In principle, this piece of information would allow me to impute a labor input variable that included both types of workers along the lines of Baily et al. (1992) or Davis and Haltiwanger (1990). The problem is that I would have to drop 1931 since I have no information on salaries in that year. However, comparing the ratio of total salaries to total wages over the three years with data, I find little change in the mean ratio. Therefore, I simply assume that total workers (wage earners and salaried), which is equal to my labor input measure, are a constant multiple of total wage earners. I also inflate the total wage bill by the same multiple when I calculate production elasticities.

Finally, to reduce measurement error, I trim the 2% tails of the distribution for $TFPR$, $TFPQ$ then recalculate production elasticities and plant productivities. This is a slightly broader cut than the 1% trim than HK. Also, I eliminate any plants that report less than 50% of their revenue from the industry’s primary product. An appendix collects a number of robustness checks with regards to the empirical results. These checks include varying the percentage of the tails trimmed, different specifications for output, and using hours worked for the limited years that I have.
Define

\[
\log \widetilde{TFP_Q}_t = \frac{1}{N} \sum_i \log TFPQ_{it}
\]

\[
\log \widetilde{TFP_R}_t = \frac{1}{N} \sum_i \log TFPQ_{it}
\]

Then \(\log \tilde{TFP}_Q_t\) will be my estimate of the \(\log \Delta t\) term. Let \(\tilde{TFP}_R_{it}, \tilde{TFP}_Q_{st}\) denote the deviations of the log firm value from the industry-year log average. The standard deviation of these deviations are my estimates of \(\sigma_{At}, \sigma_{Rt}\). In an appendix, I show that these deviations from industry averages are correlated with exit decisions suggesting that these differences are economically meaningful and not simply measurement error.\(^{29}\) I also calculate the correlation between the deviations for a given year and industry, \(\rho_{QR_t}\).

My measure of the efficient level of productivity is given by

\[
\log TFP^* = \frac{1}{\psi - 1} \log \left( \frac{1}{N} \sum_i TFPQ_{it}^{\psi - 1} \right)
\]

as implied by the model. To calculate the efficient level of productivity, I need to set a value for the elasticity of demand \(\psi\). For “illustrious” purposes, I will choose a value of \(\psi = 4\) in line with HK. I will also show how the fraction of the productivity declines explained by misallocation vary as \(\psi\) changes over a reasonable range of values from the literature (Hendel and Nevo, 2006). As emphasized above, one does not have to think about \(\psi\) structurally but instead as representing different \textit{ad hoc} assumptions about how to aggregate plant productivities without having to specify the pricing structure.

5 Results

Previewing the results, I find that increases in misallocation in the cement industry can explain nearly the total fall in productivity between 1929 and 1931. For 1933 and 1935, depending on the value \(\psi\), the fraction explained is between 10 and 20%. For manufactured ice, an increase in misallocation can potentially explain 50% of the decline in productivity between 1929 and 1935.\(^{29}\) They also display similar levels of autocorrelation to modern estimates also suggesting at least no greater degree of measurement error relative to modern data.
There is a slight decrease in misallocation between 1929 and 1931 as ice output rises. I find that both sources of misallocation $\sigma_R, \rho_{RQ}$ play important roles in the overall dynamics.

It is important to emphasize that I am deliberately not accounting for labor hoarding and changes in the composition of the labor force that can bias productivity measurements. I am solely interested in the difference between changes in the overall industry productivity and the efficient level. Changes in the efficient level, at least due to shifts in the mean, may be due to the usual explanations given for procyclical productivity. I take no stand the quantitative role of those factors except to say that they do not explain the total decline and that fully resolving the productivity puzzle during the Depression will involve them to some degree. For example, surely, a major part of explaining the sharp mean productivity declines for my data is that my productivity estimates do not include hours worked, which fall sharply over the course of the Depression. This intentional exclusion exaggerates the fall in productivity though it should not bias the results focusing on cross-sectional differences and, if anything, bias downwards the contribution of misallocation.

For both industries, $\rho_{RQ}$ shows a steady increase over the whole period. On the other hand, $\sigma_R$ displays a countercyclical pattern with a decline for ice between 1929 and 1931 as ice output actually increases over that period. I also offer some evidence from the macaroni industry. I do not attempt to measure industry productivity because I lack a capital measure. Instead I show that the patterns in labor revenue and physical productivity closely match those for the other industries with countercyclical patterns in $\sigma_R$ and an increase in $\rho_{RQ}$.

### 5.1 Industry productivity and shifts in plant-level productivity averages

Figure 4 displays the three productivity measures for the cement industry. To reiterate, the productivity estimates here use total wage earners not hours. Almost the complete fall in productivity between 1929 and 1931 is explained by misallocation with very little movement in the efficient level though the mean plant-level productivity does fall. This suggests that there are important shifts in the dispersion of physical productivity offsetting the decline in plant-level productivity. Figure 6 shows how the fraction explained by misallocation changes with $\psi$. Changes in misallocation play a substantial role for all the years over a wide range of values for $\psi$. The smallest fraction is consistently in 1935 where the fraction hovers around 15% with $\psi$ ranging from 2 to 12. The

---

30 I exclude the intermediate year of 1933 for ice because I lack a capital stock measure.
fraction increases in 1933 and averages around 20 to 30%. Depending on the value of $\psi$ for 1931, misallocation can potentially explain the total decline in industry productivity and at a minimum, misallocation plays a substantial role of nearly 50%.

This disconnect between industry-level aggregates and plant-level means does not appear to be unique to the cement industry. Figure 5 displays the changes in industry productivity, the efficient level of productivity, and the mean productivity across firms for ice.\(^{31}\) I find that industry productivity rises slightly from 1929 to 1931 and then plummets sharply from 1931 to 1935. The initial increase might seem puzzling given all of the discussion about how productivity drops during the Depression. Part of the explanation for this is that materials inputs are not deflated almost surely overestimating productivity growth in both years. However, after 1931, productivity collapses. Note that there is no data point for 1933 because the Census did not ask firms to report their capital stocks in that year.

What is clear from Figure 5 is the large decline in industry productivity between 1929 and 1935 cannot be explained by changes in the mean plant-level productivity nor changes in the efficient level of productivity. To be sure, for 1929 and 1931, the fact that industry productivity increases more than the efficient level implies less misallocation of resources. Figure 7 shows how the fraction of productivity declines explained by misallocation changes as $\psi$ varies. Note that whether or not this fraction is increasing or not depends on the relative sizes of $\sigma_A, \sigma_R, \rho_{QR}$. The reason is that $\psi$ not only changes the losses from misallocation but also the efficient level of productivity. Higher values of $\psi$ make misallocation more costly all else equal, but they also make dispersion in $\sigma_A$ more valuable for industry productivity. First, declines in misallocation can play a major role in the slight increase in productivity between 1929 and 1931. However, over the whole period from 1929 to 1935, for a wide range of values for $\psi$, changes in misallocation explain nearly as much as changes in the efficient level of productivity.

### 5.2 Shifts in misallocation measures

I now turn to decomposing the changes in misallocation into changes in the dispersion of wedges and the correlation between wedges and productivity. Note that these results do not depend on a particular choice of $\psi$. In Figure 8, I display the statistics for cement. From 1929 to 1931, both the

---

\(^{31}\)Recall that this is an example where $\psi = 4$. 

correlation and the standard deviation of $TFPR$ increase sharply\textsuperscript{32} and then fall back slightly from 1931 to 1935. The standard deviation of physical productivity increases only slightly to begin with and then increases substantially from 1931 to 1935. These results closely match the dynamics in the interbank market, which will play a central role in the theory that I develop. Even at the end of the sample, both of these measures of misallocation are substantially elevated from the pre-Depression level while the dispersion in physical productivity is back to its original value.

Figure 9 displays the dynamics of the standard deviation of $TFPR$, $TFPQ$, and the correlation between the two for the ice industry. There is a decline from 1929 to 1931 in the standard deviation of $TFPR$ while the same measure for $TFPQ$ rises. This contributes to the better allocation of resources in this industry over the first two years of the Depression. Subsequently, the dispersion in both variables increases with the dispersion in $TFPR$ well above its 1929 value. During the whole period, the correlation shows a steady rise increasing by 10 percentage points by 1935 signaling an increase in misallocation on this dimension. These results show that both of these dimensions of misallocation play a role in explaining productivity dynamics and misallocation for this industry.

I have also collected some evidence on the macaroni industry. Because the data does not contain good capital stock measures, I restrict attention to labor productivity and do not attempt to decompose TFP shifts into efficient shifts and those due to misallocation.\textsuperscript{33} Instead I use the data to document the general patterns in the dispersion of revenue and physical productivity as well as the correlation between the two. Figure 10 shows that dispersion in labor productivity revenue increases in 1931 and then falls back in 1935 while there is basically no change in physical productivity revenue.\textsuperscript{34} Finally, there is a sharp increase and then decline in the correlation between these two types of productivity. These results serve to reinforce the patterns regarding changes in misallocation measures documented for the other two industries.

\textsuperscript{32} In the appendix, I consider a potential worry about the effect of measurement error on $\rho_{RQ}$ over time.

\textsuperscript{33} The macaroni industry includes all kinds of dried pasta from spaghetti to egg noodles though the vast majority of the firms only produce macaroni. The industry was mainly concentrated in a few states in particular New York and California. While there is some degree of differentiation between the firms, the quality differences are not large enough to make quantity comparisons across firms meaningless. Alexander (1997) argues, at this time, the industry contained three main types of producers: small mom-and-pop operations that sold locally and large, industrial concerns that shipped nationally, and a middle tier of regional producers. The large firms used large scale production processes that made them much more efficient than the small producers. Hence, as Alexander points out, this created a major disparity in the costs of production. Both the regional producers and the mom and pop stores were at a major cost disadvantage to the large producers though at least the smallest stores could attempt to differentiate their product.

\textsuperscript{34} Due to data limitations, I exclude 1933 from the analysis.
Finally, it is interesting to note that the pattern in $TFPR$ dispersion is not the same for dispersion in $TFPQ$. Modern work by Kehrig (2011) and Bloom et al. (2011) has found strongly countercyclical revenue productivity dispersion, but these authors have had to remain silent about what that meant for physical productivity. As emphasized by Foster et al. (2008), selection in markets is on $TFPR$ not $TFPQ$. What actually matters is not whether a plant is physically productive but productive in terms of revenue. So there is no necessary reason why the two should move together and in fact for my limited set of industries, they do not. These differences matter for how changes in dispersion measures potentially drive productivity over the business cycle.

6 A Model of Financial Frictions and Productivity

“As the crisis of 1929-33 ha[s] proved, the [interbank] system has contributed to intensify cyclical maladjustments.” Palyi (1939)

6.1 Empirical Motivation

The obvious next question is what drives these changes in misallocation. I offer three related facts that motivate the model I build, which prominently features financial frictions. First, the accounting framework showed that variation in factor prices induced variation in $TFPR$. In particular, higher factor prices should be associated with higher $TFPR$. One potential source of variation in $TFPR$ is variation in the costs of working capital used to fund wage and materials bills. Ideally, I would have plant-level information about whether the borrowing rates faced by the plants. Unfortunately, the most disaggregated data on lending rates is at the state-level from Bodenhorn (1995). Table 1 shows the results of regressing the deviation of $TFPR$ from its industry-year average on state lending rates. I control for the deviation of a plant’s wage from the industry-year average, which is potentially another large source of variation in $TFPR$. The results show a clear positive relationship between state-level interest rates and $TFPR$. A one percentage point increase in the lending rate in the preferred specification increases $TFPR$ by .026 percentage points. Relative to the standard deviation of $TFPR$, this is about a 1% increase, a non-trivial amount.

35I construct the average wage by dividing total wage bill by a constructed total hours measure for 1929, 1931, and 1935.
Second, this regression implies that the dynamics of the dispersion of borrowing rates induce similar dynamics in the dispersion of TFPR. In fact, there is some evidence that the dynamics of the dispersion of interest rates track those of misallocation. Figure 15 shows a sharp increase in the dispersion of lending rates measured both by the standard deviation and interquartile range. These changes are not driven by outliers in 1933 as I have trimmed the high and low observations for each year. Furthermore, spreads between Baa bond yields and the Treasuries increased by more than 400 basis points between 1929 and the peak in 1933 (Calomiris, 1993). By way of comparison, the spread between Baa and Aaa industrial bonds during the most recent crisis only increased by 200 basis points (Gilchrist and Zakrajsek, 2011).36

What drives these changes in the dispersion of lending rates is the behavior of the interbank markets. This is period of U.S. economic history where branching was severely restricted. There was no interstate branching and in the majority of states, banks could not open up other branches even within the state. The lack of branching made banks very dependent on functioning interbank markets to move resources. With branching, resources can move at least relatively freely between branches of the same bank. Without branching, banks have to rely on anonymous interbank markets for liquidity.

Interbank markets at this time functioned through so-called correspondent networks. Crucial to the system were eponymous correspondent banks located in certain reserve cities discounted paper provided by small, local banks. The correspondent banks then turned around and rediscounted this paper at the relevant regional Fed. Writing at the time, Palyi (1939) aptly summarized the tight link between unit banking and the correspondent networks.

Unit banking as it exists in this country cannot be maintained unless an institutional setup is provided to keep the units in close contact with the money market...Unless we develop a similar system, which has never existed in this country, we have to rely on correspondent relationships as the only other alternative to permit the survival of unit banking, which would soon deteriorate without contact with the “fresh air” of the open money market.

This system of correspondents at least allowed the small local banks who were not even members

36Note that this is comparison is not altogether clear. There is reason to believe that the measure for the most recent crisis is an underestimate of the increase in the spread over Treasuries. Moreover, these spreads are not exactly the same as spreads in working capital interest rates across different regions. At a minimum though, if there was little movement in these spreads, it would be difficult to argue that spreads on working capital interest rates increased sharply over the same period of time.
of the Federal Reserve the opportunity to tap a broader set of funds. This system also played a
crucial role in mitigating differences in borrowing rates across regions.

So the final observation motivating my model is the collapse of the interbank markets. This is
not a new observation. Like the aggregate economy, the interbank system hit rock bottom in 1933.
In this year, the total amount of interbank deposits for all Federal Reserve member banks reached a
low point of $3.4 billion in June of 1933, a decline of 23% from its peak. After the nadir, interbank
deposits rapidly regained their pre-Depression highs by the end of 1934. There is further micro-level
evidence that the interbank market and its constituent correspondent networks were particularly
devastated during the Depression. Richardson (2007) highlighted the fragility of the correspondent
system at this time. Correspondent banks would credit checks upon receipt, and respondent banks
would do so as soon as the check was dropped in the mail. This was before the funds were ever
drawn from the check-writing bank. Because checks usually passed through at least two banks
before finally being cleared, this process led to a build up of fictitious reserves throughout the chain
of correspondences. These reserves made the system very fragile and subject to contagion. Using
archival evidence, Richardson (2007) showed that a large fraction of bank suspensions during 1931
were due to failures of correspondent banks. These three observations regarding the link between
TFPR and lending rates, the dispersion of lending rates, and the collapse of interbank markets
highlight the chain of reasoning that I will attempt to capture in my theoretical model.

6.2 Firms

I now present a simple static model to explain the losses in productivity due to misallocation
stemming from financial frictions exacerbated by the banking collapse. The model focuses on the
role that banks play in reallocating resources from unproductive to productive firms. It points
to a particular shock to banks, an increase in the marginal cost of leverage, as the culprit for
the decline and part of the recovery in productivity. When it becomes more costly for banks to
obtain funds through the interbank market, resources become “stuck” in unproductive locations
and productivity suffers.

There is a continuum of geographically separated regions (“islands”) and on each island, there
is a continuum of firms. On island $i$, all firms are the same and produce variety $i$. Final output is a Dixit-Stiglitz aggregator of all the types

$$Y = \left[ \int_0^1 y_i^{\psi-1} \psi \, di \right]^{\frac{\psi}{\psi-1}}$$

For now, I will take final demand $Y$ as exogenous. Firms operate a linear production technology in labor alone

$$y_i = A_i L_i$$

It would not be difficult to extend the analysis to a constant returns to scale production function that included other factors of production. However, since my empirical analysis focuses solely on $TFPR$, my theoretical focus will similarly abstract from the different wedges. At the beginning of the period, each island receives a productivity draw $A_i$ from a log normal distribution with mean 0 and variance $\sigma_A^2$. Shocks are i.i.d. across islands and independent over time as well.

Firms have a working capital constraint that requires them to borrow up front to pay their wage bill, e.g., Christiano et al. (2005); Barth and Ramey (2001); Christiano et al. (2010). Working capital constraints have also been emphasized by the literature examining sudden stops in emerging markets as a potential key source of amplification (Neumeyer and Perri, 2005). Firms can fund that wage bill by borrowing from only banks on their own island at rate $r_{fi}$. Hence, they maximize

$$p_i y_i - r_{fi} w L_i$$

where they face demand curve derived from the profit maximization problem of the final goods producer,

$$\frac{p_i}{P} = \left( \frac{y_i}{Y} \right)^{\frac{1}{\psi}}$$

---

37 There is a slight complication here. Because I will require a firm to obtain credit from a bank on its own island, to insure that price taking of interest rates is a reasonable assumption, I need many firms on a given island. The issue with this assumption is that it then makes the assumption of monopolistic competition suspect. To justify this assumption rigorously, I would have to add another layer of product differentiation within a given island. To ease exposition, I assume this issue away.

38 I will return to using the term “firm” rather than “plant.”

39 An interesting extension would be to allow multiple factors of production with differences in the pledgability of the different inputs. In particular, one might think that it is easier to use materials purchased with a loan as collateral than labor inputs. In this case, there might be a wedge between the rates a plant can borrow for materials versus labor. Shocks to the financial shock may then have asymmetric effects on the different interest rates and generate different dynamics for labor versus materials wedges.
and the production function $y_i = A_i L_i$.

This assumption about the local nature of firm finance is very natural and in part motivated Bernanke (1983b) to argue for the presence of non-monetary effects of bank failures. Banks in his view embodied information about the quality of various local projects. When a bank fails, its unique information is destroyed and only slowly over time is it built back up again. In the meantime, firms with profitable projects have to make due with limited access to credit. Since Bernanke’s pioneering work, the local connection between firms and banks in the Depression has been stressed by a number of papers. Calomiris and Mason (2003) document a positive relation between changes in building permits and deposit growth over the period of 1930 and 1932. Some of my own work (Ziebarth, 2011) has found a connection between local bank failures and economic outcomes using an “exogenous” banking crisis.\(^{40}\)

The optimal choice of labor solves

$$r_f w = Y^{\frac{1}{\psi}} \left( \frac{\psi - 1}{\psi} \right) A_i^{\frac{\psi - 1}{\psi}} L_i^{-\frac{1}{\psi}}$$

where I have normalized the final price index $P$ to 1 without loss of generality. Dividing the optimal choices for firms on island $i, j$ yields an expression useful for later

$$\frac{r_{fi}}{r_{fj}} = \left( \frac{A_i}{A_j} \right)^{\frac{\psi - 1}{\psi}} \left( \frac{L_i}{L_j} \right)^{-\frac{1}{\psi}}$$

which shows that the ratio of labor use across islands is related to the ratio of both productivities and interest rates across islands. Now I calculate $\text{TFPR}_i$ as

$$\text{TFPR}_i \equiv p_i A_i = A_i \left( \frac{y_i}{Y} \right)^{-\frac{1}{\psi}} = \frac{w r_{fi}}{Y^{\frac{1}{\psi}} \left( \frac{\psi - 1}{\psi} \right)}$$

This implies that ratio of $\text{TFPR}$ for any pair of islands $i, j$ is given by

$$\frac{\text{TFPR}_i}{\text{TFPR}_j} = \frac{r_{fi}}{r_{fj}}$$

\(^{40}\) These issues could be mitigated to a certain extent by plants that were part of a multi-plant firm. In this case, resources could flow between the plants insulated from breakdowns in the interbank market.
Firms on islands with higher interest rates have higher levels of TFPR reflecting the fact that they are constrained from fully expanding output to the efficient scale.\footnote{Note that this model abstracts from credit rationing in the sense that certain firms are not simply excluded from the credit market. An extension I consider allows for some firms to be shut out of the market.} In fact,

\[
\sigma_R = \frac{w}{Y^{1/\delta}(\sigma-1)}\sigma_{r_f}
\]

where \(\sigma_{r_f}\) denotes the standard deviation of (log) working capital interest rates. Therefore, any shock that increases the interest rate spread on working capital loans will increase the dispersion of TFPR. This is not a surprising finding as \(r_{fi}\) is a direct analog of \(1 + \tau_i\) in the accounting framework. The idea that measures of dispersion in TFPR are closely related to dispersion in borrowing costs is similar in spirit to Gilchrist and Zakrajsek (2011). I now turn to the banking sector to close the model and determine the working capital interest rates.

6.3 Banks

There is a continuum of banks on each island. Abstracting from differences across the island, each bank starts out with net worth \(N\). To finance working capital loans \(H_i\), banks use their net worth and interbank loans \(b_i\) (\(b_i \geq 0\) implies a bank is borrowing funds). The assumption that commercial banks are mainly in the business of short term loans is in line with much of the evidence from the time. White (2000) notes that commercial banks by “law and tradition” specialized in short term loans to fund materials and labor outlays. This was distinct from the role played by investment banks in facilitating long-term investment. Of course, the collapse of investment banks play a potentially major role in explaining the precipitous decline in investment and consumer durable purchases. However, I will abstract from that separate question for now to focus on this particular type of intermediation.\footnote{Another main source of funding for commercial banks is deposits. In an extension, I consider a deposits choice by the households. However, in the context of that extension, they play a role no different than capital. So for the time being, one could just as easily think about \(N\) as combining both of these sources of funding. To be sure, deposits are callable and they may be an important source of funding needs through the interbank market.}

So the flow of funds constraint is given by

\[
H_i = b_i + N
\]
As noted above, banks can only fund projects on their own island and can only obtain additional funds from other banks through the interbank market at $r_b$. This assumption is motivated by an important feature of the banking system, which is its highly localized nature due to regulatory constraints on branching.

The financial friction I impose is a cost to leverage $\Omega$. In the current partial equilibrium setting, I make no assumption on where $\Omega$ comes from only that $\Omega' > 0, \Omega'' \leq 0$. So profits of a bank are given by

$$r_{fi}H_i - r_bb_i - \Omega \left( \frac{H_i}{N} - 1 \right)$$

This kind of cost of leverage can be motivated in a dynamic setting in a variety of ways. For example, banks could face an incentive problem where the market limits their leverage because of fears that the bank will abscond with assets (Gertler and Kiyotaki, 2010). Limitations on leverage can also be motivated by problems due to costly state verification or margin value-at-risk requirements (see Brunnermeier et al. (2011) for an extensive survey).

The particular type of motivation I would like to focus on is adverse selection in the interbank market due to a lemons problem. Stiglitz and Weiss (1981) were the first to study this issue in the context of imperfect information about the riskiness of a project. They showed that in this setting, credit might be rationed as higher interest rates would not increase the expected profitability of a loan. Instead it would draw a riskier pool of firms applying for funding. citetkurlat:2011 has studied a model of adverse selection with private information about the return of a project rather than its riskiness. He shows that with sufficiently severe shocks, financial markets shutdown and the most productive entrepreneurs are unable to invest.

Consider the following situation. As before, there are island-specific productivity shocks that will be common knowledge to firms and banks on the given island. However, that piece of information will not be observed by banks on other islands. After this shock has been realized and banks commit to a certain amount of working capital loans, a lemons shock $\lambda_i$ occurs meaning a fraction $\lambda_i$ of the projects already committed to be funded will be produce nothing. Like the productivity shock, this will be an i.i.d. shock across islands and will be private information as well. An equivalent way to conceptualize the shock is that there is a bank run shock where some banks are

---

43 To be sure, in that setting, banks ended up facing a “hard” leverage constraint that varies endogenously. I study a smooth version of that problem.
hit with particularly heavy redemption requests by depositors. This too leads to particularly high
demand for funds to satisfy creditors. While potentially more appealing from the viewpoint of the
history of the Depression, I continue to focus on the lemons shock for tractability.

Following the lemons shock, banks can attempt to raise funds in the interbank market by
effectively selling both the lemon and non-lemon projects. While at the same time, they must
respect the constraint that they fund all projects with funds committed. The problem is that the
interbank market cannot distinguish between two types of banks with high borrowing demands:
those with high productivity projects versus those with lots of lemons. There is thus two sources
of private information that cannot be screened out though the single instrument in the form of
interbank interest rate. Banks will always sell their lemons in the market as long as the price i.e.
the inverse of the interest rate is greater than 0.

The question is whether or not banks with good projects prefer to raise funds by selling them
into the market versus funding them from their own capital. The issue is that the group of banks
with the heaviest borrowing needs will also be subject to the most severe adverse selection problem.
This will drive down the price banks receive for the loans that they sell leading to higher borrowing
rates for the banks with the most productive projects. Thus the most productive banks will be
unwilling to sell their most productive projects, or equivalently, they will face an endogenous limit
on leverage. The degree of the adverse selection problem will depend on the relative variances of
the productivity shock versus the lemons shock. When the variance of the lemons shock increases
holding fixed the mean size of the lemons shock, then the adverse selection problem becomes more
severe and the limits on leverage more stringent. The reason for this is that as the variance of
lemons shock increases, it becomes more difficult to infer from a bank’s lending needs the quality
of the projects it has in its portfolio. I do not formalize the intuition here, but simply continue
with the exogenous formulation for $\Omega$.

Then the optimal choice for interbank borrowing is given by

\[ r_{fi} - r_b = \Omega' \left( \frac{b_i}{N} \right) \]

To solve the model in closed form, I will take a first order approximation to $\Omega'$ about $b_i = 0$. Then
under this approximation,
\[ \frac{b_i}{N} = \frac{r_{fi} - r_b}{\omega} \]
where \( \omega = \Omega'(0) \). This expression implies that a particular bank’s leverage is a smooth increasing function of the differential between the rate it can charge firms on its island and its borrowing costs from the interbank market. There is an interesting limiting case where the credit market imperfections disappear. If \( \omega \to 0 \), then \( r_{fi} \to r_b \) for all \( i \) and there is no dispersion in TFPR across islands. In this limiting case, banks can take advantage of any arbitrage opportunity by leveraging up with no cost. Hence, there cannot be any interest rate differentials across islands.\(^{44}\)

I will approximate the solution around a particular level of productivity \( \bar{A} \) such that if \( A_i \leq \bar{A} \), banks on those island will be net interbank lenders and vice versa. For \( A_i = \bar{A} \), then it must be the case that
\[ r_{fi} = r_b \]
Setting \( b_i = N - wL_i \) to 0 pins down the productivity cutoff \( \bar{A} \)
\[ N = w\bar{L} = w^{1-\psi}L\bar{A}^{\psi-1}r_b^{-\psi} \]
where \( \bar{L} \) is labor demand for this type of firm.

6.4 Market clearing

Loan market clearing implies that the total amount of working capital loans on a given island has to be equal to the amount of bank net worth on the island plus interbank borrowing.
\[ wL_i = N + b_i \Rightarrow wL_i = N \left( 1 + \frac{r_{fi} - r_b}{\omega} \right) \]  
(5)
This relationship delivers a positive relationship between firm borrowing rates and total wage bill taking everything else as given. Ceteris paribus more productive firms pay higher interest rates, a slightly counterintuitive result. If the quality of firms were with regards to the risks of bankruptcy,

\(^{44}\)Note that there is another constraint on the choice set which is that \( b_i \geq -N \), i.e. banks cannot lend out more in the interbank market than they have in capital. This is a potentially binding constraint for banks on very unproductive islands. However, because the marginal product of labor goes to \( \infty \) as the use of labor goes to 0, in equilibrium, it will never be optimal for banks to exceed this interbank lending constraint.
then intuition would suggest that the lower quality firms with a higher probability of failure would face higher working capital interest rates to compensate banks for the risk. However, in this model as in Gertler and Kiyotaki (2010) with a quasi-fixed supply of loans and no internal supply of funds, more productive firms have a higher demand for loans, and, hence these firms must pay higher interest rates.

Interbank clearing requires that

\[
\int b_i di = 0
\]

Subbing for the expression for optimal interbank lending,

\[
\int_{0}^{\infty} N \left( \frac{r_{fi} - r_b}{\omega} \right) dF(\log A_i) = 0
\]

(6)

where \(F\) is the cdf of the normal distribution function with mean 0 and standard deviation \(\sigma\). Then I have

**Proposition 6.1** \(\tilde{r}_f = r_b\) where \(\tilde{r}_f = \int_{0}^{\infty} r_{fi} dF(\log A_i)\) is the average working capital interest rate.

It is useful to note here that this model will generate a distribution of leverage ratios across banks though the overall banking sector will not be leveraged. The lack of overall leverage follows from the aggregate loan market clearing constraint. Again this assumption can be relaxed in a richer model where banks can also raise funds through the retail deposit market before the productivity shocks are realized.

Equation 5 will be the key equation since it pins down the relationship between \(r_{fi}\) and \(A_i\).

Using the labor demand expression to solve for \(wL_i\),

\[
w^{1-\psi} L A_i^{\psi-1} r_{fi}^{-\psi} = N \left( 1 + \frac{r_{fi} - r_b}{\omega} \right)
\]

Denote the implicit relationship between \(r_{fi}\) and \(A_i\) by \(r_{fi} = g(A_i)\). It is useful to note that \(g\) is a strictly increasing function as demand for loans is strictly increased in \(A_i\). Differentiating with respect to \(A_i\), I have

\[
\frac{\partial \log r_{fi}}{\partial \log A_i} = \frac{\psi - 1}{\psi + \frac{w^{\psi-1} N A_i^{1-\psi} r_{fi}^{\psi+1}}{L \omega}}
\]

(7)

Therefore,
Proposition 6.2 To a first order approximation about $\log A_i = \log \bar{A}$, $\log R_{fi}$ will also be normally distributed with mean $\log R_b$ and variance

$$\sigma_R = \sigma_A \cdot \rho_{QR}$$

This first-order approximation also implies that

$$\rho_{QR} = \frac{\psi - 1}{\frac{Nq}{\omega} + \psi}$$

The expression shows that as frictions in the interbank market go to 0 i.e. $\omega \to 0$, then the standard deviation of $TFPR$ goes to 0 along with the correlation between the $TFPR$ and $TFPQ$. To reiterate in the case where banks are not punished for being highly leveraged, any differences in firm borrowing costs must be arbitraged away. Therefore, there is no variation in firm borrowing costs and the correlation must be 0.

The model here is slightly counterfactual as it draws a very tight one-to-one link between $\sigma_R$ and $\rho_{QR}$ though it is clear from the data that the relationship is not nearly so simple. This tight link depends on the fact that $\sigma_A$ is taken as exogenous. Any log-linear approximation will have this problem as both $\rho_{QR}$ and $\sigma_R$ are linear functions of the derivative of relationship between $R_{fi}$ and $A_i$. A richer model is discussed in the appendix with entry and exit driving variation in $\sigma_A$, which opens up the possibility for different dynamics of $\rho_{QR}$ and $\sigma_R$. Also, my approach ignores non-linear behavior in the tails of the productivity distribution brought on by the fact that leverage scales with the difference between $r_{fi}$ and $r_b$ rather than the ratio of $r_{fi}$ to $r_b$.

To solve the model, note that aggregating loan market clearing across all islands along with interbank clearing implies $w = \frac{N}{T}$ and labor clearing will be trivially satisfied. Then I simply need to solve for $r_b, \bar{A}$ to fully characterize the equilibrium. Under my approximation, I have that

$$\log r_{fi} = \log r_b + \rho_{QR}(\log A_i + \log \bar{A})$$

Recall that

$$\tilde{r}_f = \int_0^\infty r_{fi} d\Phi(\log A_i) = r_b$$

(8)
Substituting my expression for $\log r_{fi}$ into equation 8, I find that

**Proposition 6.3** The values of $\bar{A}, r_b$ are determined by the intersection of the following two curves

\[
\log \bar{A} = \frac{1}{2} \frac{\sigma_A^2 (\psi - 1)}{\frac{N r_b}{\omega}} + \psi
\]

(9)

\[
\log \bar{A} = \frac{\psi}{\psi - 1} \log r_b N - \frac{\psi}{\psi - 1} \log L
\]

(10)

where the second equation is a rewritten expression for the cutoff $\bar{A}$. Note that the cutoff $\bar{A}$ is a direct function of $\rho_{QR}$, $\log \bar{A} = \frac{1}{2} \sigma_A^2 \rho_{QR}$.

These equations characterize equilibrium in the interbank market. Equation 9 determines a negative relationship between $r_b$ and $\bar{A}$. An increase in $r_b$ implies a higher supply of interbank loans from banks with marginal products. This leads to a lower productivity threshold as marginal firms are able to take advantage of the increased supply. Equation 10 on the other hand determines a positive relationship between the two. When $r_b$ increases, this increases the threshold productivity since only relatively more productive firms are able to compensate banks for foregoing higher returns in the interbank market. Note that both equations only depend on the product of the interbank rate and bank capital, $r_b N$. Therefore,

**Proposition 6.4** Shocks to $N$ do not affect the distribution of $TFPR$ nor $TFP$.

Decreases in $N$ are completely compensated by increases in $r_b$ and vice versa. It is also clear from this that shifts in the overall leverage ratio of the financial sector are not playing a role. In fact for my setup, this ratio is fixed to a value of 1.

Under the linear approximation, calculating the effects on productivity is trivial since as before we have

\[
\log TFP = \log TFP^* - \frac{\psi}{2} \sigma_R^2 - \rho_{QR} (\psi - 1) \sigma_Q \sigma_R
\]

Hence,

**Proposition 6.5** Increases in the marginal cost of leverage $\omega$ increase both the variation in $TFPR$, $\sigma_R$, and the correlation $\rho_{QR}$ thereby reducing $\log TFP$.

It is clear that a shock to $\omega$ only affects equation 9 shifting it rightwards. This leads to an increase
in $\rho_{RQ}$ and, thereby, an increase in $\sigma_R$ and a loss in productivity.\footnote{One thing interesting to note about the model is that it naturally generates procyclical productivity independent of shifts in the marginal costs of leverage. Recall that I took final demand $Y$ to be exogenous and that I normalized total labor supply to}

$$L = Y \left( \frac{\psi}{\psi - 1} \right)^{\phi}$$

Note that log $\bar{A}$ depends negatively on $L$. Therefore, a demand shock that increases $Y$ drives down log $\bar{A}$ and with it, $\rho_{QH}$ and $\sigma_R$. This will increase overall productivity. Similarly if I had included an aggregate productivity shock, this would enter positively into $L$ and hence, supply shocks would be multiplied endogenously in this framework. So even abstracting from business cycles driven by financial factors such as changed in $\phi$, my model delivers procyclical labor productivity.

\footnote{There is only fragmentary evidence from modern data on the question of the cyclicality of the dispersion of leverage ratios. He et al. (2011) document that during the most recent crisis, hedge funds and the broker/dealer sector shed assets while the commercial banking sector increased asset holdings over this time. This is consistent with the idea that the variance in leverage across financial intermediaries declined over this time assuming hedge funds started with higher leverage ratios. Papers by Gatev and Strahan (2006) and Pennacchi (2006) also discuss the reintermediation process that goes on during crises whereby certain financial institutions have to take on the assets shed by other financial institutions.}

7 Empirical evidence for the role of the collapse of the interbank market in the productivity decline

In this section, I first show that evidence on the banking sector at this time is consistent with the predictions of my model and then link those bank variables to my micro-level data to document some predictions of my theory.

7.1 Evidence from Banking Data

One testable prediction of my model and the shock that it emphasizes is that while the dispersion in TFPR is countercyclical, the dispersion in bank leverage ratios is procyclical. Previously highly leveraged banks reduce their leverage and banks with low levels of leverage increase their asset holdings. Using data disaggregated to the state-level, Figure 2 plots this crucial variable. It in fact moves quite closely with the dynamics of productivity showing a sharp fall between 1929 and 1933 and then a rapid recovery from then onwards. This fact confirms the prediction of the model along this dimension. \footnote{There is only fragmentary evidence from modern data on the question of the cyclicality of the dispersion of leverage ratios. He et al. (2011) document that during the most recent crisis, hedge funds and the broker/dealer sector shed assets while the commercial banking sector increased asset holdings over this time. This is consistent with the idea that the variance in leverage across financial intermediaries declined over this time assuming hedge funds started with higher leverage ratios. Papers by Gatev and Strahan (2006) and Pennacchi (2006) also discuss the reintermediation process that goes on during crises whereby certain financial institutions have to take on the assets shed by other financial institutions.}

But what about other measures of the health of the banking sector? My model, while making a strong prediction about the procyclicality of the dispersion of leverage, also makes equally strong predictions that these productivity changes need not be correlated with other banking measures such as leverage ratios or the level of bank capital. The declines in the banking sector over the
first four years of the Depression are all too clear. At an aggregate level between 1929 and 1933, the number of banks drops from around 24,000 to 14,000, a 54% decline.\footnote{All the statistics reported in this paragraph come from Board of Governors of the Federal Reserve System (1941).} Capital for all banks in the Federal Reserve system falls by 33% over a similar time frame and only recovers around 5% from 1933 to 1935. Banks in 1929 were leveraged 9.5 to 1 and over the course of the first half of the Depression, they deleverage with the leverage ratio falling to around 8 in 1933. Hence, when asset prices collapse, the deleveraging process has multiplier effects on total loans, which fall by 66%, two and half times the decline in capital.

So these declines in banking variables can surely match the downturn in productivity. Figure 2 confirms that fact with data from Comptroller of the Currency (1937), a more disaggregated source.\footnote{Unfortunately, the data is still only at the state-level. State borders were relevant economically since there was absolutely no interstate banking at the time.} The drops in capital, leverage, number of banks, and so on all line up well with the decline in productivity. However, each of these variables struggles to match other dynamics of aggregate productivity. For example, overall leverage is declining well in advance of the drop in productivity so that by 1929, it is already quite close to its nadir 1933. On the other hand for bank capital, while there is a precipitous drop between 1929 and 1933, there is no real recovery afterwards. In fact, bank capital was still 13% below its pre-Depression peak in 1941. These facts provide additional evidence for the particular shock that I emphasize.

7.2 Cross-sectional evidence

I now turn to regression evidence using my plant-level dataset and banking data from Comptroller of the Currency (1937). The first implication of the model I test is the following. When interbank markets are functioning well, economic outcomes are not that dependent on local banking measures. Conversely, when interbank markets have shut down, economic outcomes, in particular \( TFPR \), is highly dependent on local bank outcomes. This suggests that regional dummies should explain more of the variation in \( TFPR \) during the crisis years of 1931 and 1933. This, in some ways, is an oblique test of my model. However, it has the advantage that it does not require me to take a particular stand on what the proper measure of banking is at the local level.

I implement this test by separately regressing the plant-level data on interactions between industry and state fixed effects for each year separately. The results in Table 2 in fact show a sharp
decline in 1931 and a rebound in 1935.\textsuperscript{49} The $R^2$ of the regression with interactions between state and industry fixed effects in 1929 is around 7\% and this jumps to 12\% in 1931 before falling back to its previous level in 1935. This is a statistically significant difference.\textsuperscript{50} For the regression with state and industry effects separately, a similar pattern holds though the difference between years is not statistically significant.

A related implication of the model is that when interbank markets shutdown, there should be a positive relationship between bank leverage and $TFPR$. Consider the limiting case where interbank markets are perfect, then there should be no correlation as there is no variation in $TFPR$. However, during the crisis period, the banks with the best projects are restricted from leveraging up further thereby generating a positive correlation. Table 3 regresses $TFPR$ on the overall leverage ratio of commercial banks in a given state. What is striking is that there is basically no relationship between the variables in 1929 and strongly positive one in 1931 and then a smaller effect in 1935 that is imprecisely estimated. To interpret the results, the standard deviation of log leverages ratios is around .3. So a one standard deviation increase in leverage ratios increases $TFPR$ by around .03 log points, which is around 10\% of the standard deviation. Both of these tests provide some cross-sectional evidence for my model. The other two columns show a couple robustness checks. The pattern is similar though the reversion in 1935 to the pre-crisis correlation is not nearly as strong.

7.3 A comparison: Canada during the Great Depression

More evidence on the effects of the banking crisis on productivity comes from comparing the U.S. experience during the Great Depression to Canada’s. Over a similar period of time to the U.S., Canadian GNP falls by around 40\% relative to a 2\% trend between 1929 and 1933.\textsuperscript{51} The U.S. experiences a decline of around 38\% over the same time. Comparing TFP changes, Canada’s aggregate productivity falls by around 15\% while U.S. productivity falls by 20\% relative to trend. If not in the context of the Depression, this difference of 5 percentage points would seem quite large. But the differences between the two are much starker if one considers productivity stripping out

\textsuperscript{49}I drop the data for 1933 because of the fact that I do not have capital measures for the ice data. This makes the comparison of variation explained across years invalid. For this reason, I simply exclude this year.

\textsuperscript{50}I bootstrap the standard errors since the test statistic, a comparison of the $R^2$ across regressions, is rather non-standard.

\textsuperscript{51}All numbers are from Amaral and MacGee (2002).
the government and agricultural sectors. With this measure, the decline in U.S. TFP is nearly double that of Canada’s between 1929 and 1933. What is striking is the divergence in productivity after 1933. While U.S. aggregate and private non-agricultural productivity begins to recover in 1935, Canadian TFP stubbornly remains well below trend.

What explains this difference in the behavior or productivity? One of the biggest differences is the fact that Canada did not suffer a banking crisis like the U.S. No Canadian banks failed during the Great Depression though the economy did suffer a debt crisis brought on by an unexpected deflation (Amaral and MacGee, 2002). The fact that a crisis was averted may have been partly due to the fact that Canada did not have branching restrictions (Bordo et al., 1994). Instead of the fragmented U.S. banking system, the banking market in Canada was heavily concentrated with a few large banks owning branches in nearly every small town. Much like today, these wide branch networks allowed for the movement of resources within a bank itself. By insulating a fraction of resource flows from the vagaries of interbank markets, this limited the potential damage on productivity from a collapse in interbank funding. My model suggests then that this is no coincidence that the decline in TFP is much larger for the U.S. Furthermore, it is not a surprise that the paths of the two diverge after 1933 as the U.S. interbank markets slowly begin to heal and confidence in the banking sector is restored.

8 Conclusion

I have proposed a new hypothesis to explain part of the sharp decline in aggregate TFP during the Great Depression. It identifies an increase in the misallocation of resources across plants as playing a crucial role. To develop this hypothesis, I collected a plant-level dataset of the two industries with supporting evidence from a third industry. Across all industries, changes in misallocation explain large fractions of the decline. The fraction is about 15% of between 1929 and 1935 for cement and 50% for ice. I find that two sources of misallocation, dispersion in $TFPR$ and correlation between $TFPR$ and $TFPQ$, both show sharp increases and contribute to the overall productivity decline.

Shocks to the financial sector can provide a plausible explanation for this productivity decline. I develop a model with heterogeneity in productivity across plants that rely on banks for working

52 There are good reasons to ignore the government sector since my model does not strictly apply to outcomes there. Similarly for agriculture.
capital. Banks face a convex cost of taking on more leverage stemming from adverse selection. Hence, banks are unwilling to take on an arbitrarily large amount of leverage and interest rate differentials across islands exist. Moreover, since the most productive firms require the most resources, the convex cost of leverage falls disproportionately on this group. This leads to a positive correlation between revenue and physical productivity. In response to a shock to the marginal cost of leverage, spreads in interest rates rise, the correlation between productivity and working capital costs increases, and productivity declines. Interestingly, changes in the actual level of bank capital or leverage do not impact measures of dispersion and productivity.

There is much work remaining to be done. Recently another explanation has come to interpret differences in revenue productivity in modern data as related to plant-level uncertainty and not as misallocation per se (Bloom, 2009). When there are fixed costs to adjustment, following an increase in uncertainty, reallocation freezes as firms exercise the option of waiting. This can lead to a decline in productivity. Others such as Romer (1990) have argued that uncertainty increased sharply with the stock market crash of 1929. This suggests that this uncertainty interpretation could also explain the decline in productivity. It is important to emphasize that the uncertainty view does not invalidate my empirical findings on the cross-sectional changes in $TFPR$. It is instead a different way to interpret those results in terms of uncertainty rather than misallocation. While I would argue that the uncertainty explanation has difficulty explaining the cross-sectional results presented, work to more carefully formulate a test to discriminate between the two is an important avenue for future work.53

More work is needed to extend the analysis to other industries and ask whether similar results hold there. In particular, a set of industries along the lines of Foster et al. (2008) that have very homogeneous products would be particularly insightful. This work has also not attempted to address what type of wedges be they labor, capital, or output drives the dispersion in $TFPR$. Understanding the source may provide crucial evidence for or against my particular explanation. In the future, it would also be useful to link the Census plant-level data with data from Dun and Bradstreet, which was a credit rating firm at the time. These D&B records at the firm-level provide information about a firm’s net worth and a credit rating. This would allow me to use variation

\footnote{A potentially useful source of variation here would be to consider the differences in banking markets across countries and how those relate to declines in productivity. The current Great Recession might also provide useful insights on this account.}
in the exposure of the plants to financing requirements. But most importantly, subsequent work should ask whether the “classical” explanations of procyclical productivity in conjunction with my approach can finally solve one of the more vexing problems of the Depression – the decline in aggregate productivity. This paper has attempted to take one small step towards that ambitious goal.
9 Appendix: Two Data Quality Checks

In this appendix, I consider two checks on to what extent the data is severely contaminated with measurement error. First, I ask whether $TFPQ$ or $TFPR$ predict exit decisions. The outcome of this exercise provides some evidence on the economic significance of the differences in these productivity variables. To do this, I estimate a simple probit for exit on revenue and physical productivity using the data from cement, ice, and macaroni. This will be labor productivity for macaroni and total factor productivity for the other two industries. Results are reported in Table 4. Suggesting that these differences in productivity are meaningful, $TFPQ$ or $TFPR$ both have strong negative effects on the probability of exit. The marginal effect for $TFPQ$ calculated from the mean is around 8 percentage points off an average exit rate of 32% per census. The effect is not quite as strong for $TFPR$ with an marginal effect of closer to 7 percentage points. This contradicts slightly the finding in Foster et al. (2008) who find that revenue productivity is a stronger predictor of survival than physical productivity.54

A further check on the validity of these productivity differences involves calculating the persistence of these productivity measures. Measurement error usually by assumption is not correlated or, at least, only weakly correlated over time. On the other hand, a variety of studies such Foster et al. (2008) have found that productivity measures at the plant-level is highly persistent. If my data were severely corrupted with measurement error, I would expect a much lower persistence. Results are reported in Table 5. The implied annual autocorrelation for $LFPQ$ is very similar to Foster et al. (2008). I find a value of .76 only slightly lower than their reported value of .79. The results are similar for $TFPR$ where I find an annual persistence of .68 whereas they find .78.55 Finally, the autocorrelation in prices is .73 within a reasonable range of reported values from modern data. These tests do not rule out persistent measurement error driving the dispersion, but they do cast doubt on the idea that year to year variation is simply noise.

54 One interesting thing to note not reported here is that there does not seem to significant differences in terms of $TFPR$ and $TFPQ$ between continuing and entering firms. Foster et al. (2008) report that entering firms have on average lower revenue productivity and higher physical productivity.

55 A possible reason for the difference is that they annualize an autocorrelation over five years while I annualize a biennial autocorrelation.
10 Appendix: Robustness checks for empirical results

10.1 Different degrees of tail trimming

The results reported in Oberfield (2011) are very sensitive to how the tails are handled. This makes it very tenuous to draw any implications about the magnitude of misallocation. To check on this worry, I repeat my analysis varying how I trim the tails. In Figures 11 and 12, I conduct the same exercise for the cement industry. In Figures 13 and 14, I repeat the calculations for ice trimming 1% and also trimming 3%. In both of these cases, the broad implication that misallocation plays a major role in productivity dynamics is confirmed for the both more and less stringent cuts of the data.

10.2 Hours worked for labor input variable

Here I consider another robustness check using the hours per wage earner variable along with the wage earners variable to construct a total hours at the plant-level. I did not use this specification in the baseline results because the hours variable does not exist for 1933. Therefore, that observation would have to have been dropped. For these results, I also eliminate any observations that report a workweek less than 20 hours or greater than 84. The results for cement are nearly identical with a rise in the standard deviation of $TFPR$ of .25 log points instead of .3 and basically no differences for the results on the correlation. Similarly for ice, there is very little difference between this specification and the baseline in terms of misallocation measures.

10.3 Real value added specification vs. gross output specification

Another check on the results is to use real value added as the output measure rather than the direct physical output measure that I use. It is important to emphasize that this is still substantially different than the usual “real” output measures used in most studies employing plant-level data. In those studies such as Kehrig (2011), revenue or value added is deflated by an industry-level price deflator. I instead employ the real output data I have to construct a plant-level price to deflate value added. So in effect, the only difference is that in the real value added specification, I impose that the elasticity of output with respect to materials and energy is one. When I make this assumption, results are basically unchanged. There is a slightly larger increase in the dispersion of
revenue productivity for cement over the first few years and a larger increase for ice in the last 2 years. The overall implications drawn from the results are the same.

11 Appendix: Closing the Model

To close the model, I allow banks to collect deposits in the retail market at rate $r_d$ taking this rate as given. They still also have their own net worth to fund loans. After those funds have been raised, the island-specific productivity shocks are realized and banks can attempt to obtain funds from the wholesale interbank market at rate $r_b$ for lending to firms on their island. The bank's problem can be solved by backward induction. I assume that banks have perfect foresight over what rates will prevail in the interbank market though they do not know what the realization will be on their particular island. Then banks maximize

$$E \left[ r_{fi}(D + b_i + N) - r_b b_i - r_d D - \Omega \left( \frac{b_i + D + N}{N} - 1 \right) \right]$$

where $N, r_b, r_d$ are all taken as given from the point of view of the bank and I have substituted out for the flow of funds constraint. The expectation is over the distribution of $r_{fi}$ that depends on the realization of the productivity shock $A_i$. Continuing to assume the same approximation for $\Omega$, the problem is homogeneous of degree 1 in $N$. Denoting variables scaled by $N$ with a tilde, I can rewrite the problem as

$$E \left[ r_{fi}(\tilde{D} + \tilde{b}_i + 1) - r_b \tilde{b}_i - r_d \tilde{D} - \frac{\omega}{2} \left( \tilde{b}_i + \tilde{D} \right)^2 \right]$$

Similar to before, the optimal choice of $b_i$ after $A_i$ is realized (under the assumption of a linear approximation to the optimal choice) is given by

$$\frac{b_i + D}{N} = \frac{r_{fi} - r_b}{\omega}$$

This equation implies that greater deposits reduces the need for subsequent interbank borrowing. Note that with this expression, the optimized value for bank profits as a function of $\tilde{D}$ is linear in $\tilde{D}$ where the slope is $r_b - r_d$. For there to be an equilibrium, it is necessary that $r_b = r_d$. So the
level of deposits will be pinned down by the supply from households. The fact that $r_b = r_d$ is an implication of the fact that deposits and interbank funds are treated symmetrically in the leverage cost function. Given this, there is no reason to raise deposits unless the cost of deposits is cheaper than the cost of borrowing subsequently in the interbank market.\footnote{Gertler and Karadi (2011) allow for these two sources of funds to be treated differently and motivate the difference by assuming that it is more difficult to misappropriate funds garnered in the interbank market.}

I can write down the optimized level of profits scaled by $N$ as

$$r_b - \frac{N^2}{2\omega} \sigma_R^2$$

Note how optimized profits are a function of the difference between the mean return $r_b$ and the spread in interest rates $\sigma_R^2$.

I assume households maximize

$$\sum_{t=0}^{\infty} \beta^t \left( \log C_t - \frac{\nu}{1 + \pi} L_t^{1+\pi} \right)$$

where $\pi$ is the Frisch elasticity of labor supply and $\nu$ is a utility scaling parameter. For tractability following Gertler and Kiyotaki (2010), within the household, there is a $1-f$ fraction of workers and the remaining fraction $f$ are bankers. Workers supply labor and return their wages to the household. Bankers manage “banks” and return non-negative dividends to the household. I assume that there is perfect consumption insurance in the family. Households can deposit funds in their local bank and own equal shares in all of the firms across the various islands. They then face a budget constraint given by

$$C_t + D_t = \int_0^1 \pi_{it}^f di + \Pi_t^B + R_tD_{t-1} + T_t + w_tL_t$$

where $D_t$ denotes deposits, $\int_0^1 \pi_{it}^f di$ profits from firms, and $\Pi_t^B$ a net transfer from exiting banks. Each period a fraction $1-\gamma$ of bankers exit and transfers retained earnings to the household. Finally, $T_t$ represents net transfers the households receive from the government from the rebate of taxes paid by banks on their leveraged position.

The model delivers a standard consumption Euler equation

$$E_t A_{t+1} R_{t+1} = 1$$
where

$$\Lambda_{t+1} = \beta \frac{u'(C_{t+1})}{u'(C_t)}$$

As well as a standard condition for the optimal choice of labor

$$\nu L^p_t C_t = w_t$$

I assume that each period before the island-specific productivity shocks are realized, banks can move between islands to eliminate any differentials in expected returns. This eliminates the need to keep track of the distribution of bank net worths across the islands stemming from different histories of island-specific productivity shocks.

Unlike Gertler and Kiyotaki (2010), there is no particular incentive for banks to build up retained earnings since the exogenous friction imposed is never really overcome. Still for comparability, I make the same exit assumption. Then \((1 - \gamma)f\) workers become bankers each period to ensure a constant number in each. These bankers receive a small transfer \(\frac{\xi}{1-\gamma} N_t\) as startup funds from the household. So \(\Pi^B_t\) is the net transfer of funds to the household from banks exiting less transfers to new banks starting up. This term \(\xi\) will have to be calibrated and taken as parametric.

Aggregating across banks to calculate total net worth of the banking sector delivers the following law of motion

$$\frac{N_{t+1}}{N_t} = (\gamma + \xi) + \gamma \frac{r_{bt}}{2} - \frac{N_t^2}{2 \sigma_{R_t}^2}$$

Because the banks per period maximization problem is completely static, they only need to maximize period by period with no regard for intertemporal considerations.

Finally, the resource constraint states that

$$Y_t = C_t$$

As a modeling device, I will consider the leverage costs as stemming from a government imposed tax on leverage. The government balances its budget period by period rebating the revenues from
the tax on leverage to the households.

\[ T_t = \int_0^1 \omega \left( \frac{b_{it} + N_t}{N_t} \right) di \overset{\text{def}}{=} \frac{N_t^3 \sigma^2_R}{2\omega} \]

where the right hand side represents the revenue raised by the leverage tax on banks. The second equality follows from substituting in the expression for \( b_t \).

With deposits, there are only minor modifications that need to be made to the equilibrium equations. Now interbank clearing implies that

\[ w_t = \frac{D_t + N_t}{L_t} \]

The cutoff equation can be written as

\[ \left( \frac{N_t + D_t}{L_t} \right)^{-\psi} = \frac{A_t^{\psi - 1}}{r_t}^{\psi - 1} \]

Then the modified expression for \( \rho_{QRt} \) is

\[ \rho_{QRt} = \frac{\psi - 1}{\frac{(N_t + D_t)\sigma_R}{\omega} + \psi} \]

**Proposition 11.1**  *Shocks to \( N + D \) have no effect on TFPR dispersion nor productivity.*

Changes in the overall availability of resources for lending \( N + D \) will translate one for one into changes in \( r_t \). Though \( N + D \) does not affect productivity, shifts in this variable still has effects on labor demand and through that, effects on output. An appendix collects all of the equilibrium equations.

To summarize the variables determined in equilibrium \{\( r_{dt}, r_{bt}, N_t, D_t, C_t, Y_t, TFP_t, \sigma_R, L_t, \rho_{QRt}, w_t, \bar{A}_t \}\)
are defined by

\[ Y_t = TFP_t L_t \]  
\[ r_{dt} E \left[ \frac{\beta C_t}{C_{t+1}} \right] = 1 \]  
\[ \nu L_t - \pi C_t = w_t \]  
\[ \sigma_{Rt} = \rho_{QRt} \sigma_A \]  
\[ \frac{N_{t+1}}{N_t} = \xi + \gamma + \frac{\gamma}{2} R_{bt} - \frac{N_t^2}{2 \omega} \sigma_{Rt}^2 \]  
\[ \log \bar{A}_t = \frac{\psi}{\psi - 1} \log(R_{bt} N_t) - \frac{\psi}{\psi - 1} \log L_t \]  
\[ \log \bar{A}_t = \frac{1}{2} \frac{\sigma_A^2 (\psi - 1)}{N_t R_{bt} \omega + \psi} \]  
\[ w_t = \frac{N_t + D_t}{L_t} \]  
\[ \rho_{QRt} = \frac{\psi - 1}{N_t R_{bt} \omega + \psi} \]  
\[ \log TFP_t = \log A + \frac{\psi}{2} \sigma_A^2 - \frac{\psi}{2} \sigma_{Rt}^2 - \rho_{QRt} \sigma_{Rt} \sigma_A (\psi - 1) \]  
\[ Y_t = C_t \]  
\[ r_{bt} = r_{dt} \]  

11.1 A calibration exercise

In this section, I calibrate the model and consider the effect of a permanent shift in \( \omega \) on steady state values for the other endogenous variables. For most of the parameters of the model, I take the values reported in Gertler and Kiyotaki (2010). These include \( \beta, \pi, \nu, \gamma, \xi \). I choose the elasticity of substitution to be the same value as that used in the empirical work. What remains to calibrate are \( \sigma_A, \omega \). First, I choose a value of \( \sigma_A = .25 \) similar to modern estimates that examine within industry productivity dispersion (Foster et al., 2008).\(^{57}\) Finally and most importantly, I need to choose an initial value for \( \omega \). I will choose to match the ratio of bank equity to total assets, which in my model is \( \frac{N}{wL} \). From modern data, this fraction has averaged around 9%, which is the target that I will use. The values for all the parameters are reported in Table 6.

The results of the simulation are reported in Figure 16. A 50% increase in \( \omega \) leads to an

\(^{57}\)From the steady state equations, it is clear that the value for \( A \) only effects the scale of output. So it can just be normalized.
approximately 2.5% decline in productivity. My empirical estimates suggested that misallocation could explain approximately 20% of the decline in manufacturing productivity over the first half of the Depression. The overall decline was around 10% so this translates to around 2 percentage points due to an increase in $\omega$. This shift also drives an endogenous decline in bank capital, labor, and output. These declines are much larger than the fall in productivity and imply that even this relatively small fraction of productivity explained by the shock to the marginal cost of leverage could potentially explain a much larger fraction of the overall fall in output and labor employed. The intuition for the multiplier effect is that the shock to $\omega$, in turn, drags down labor demand through loan market clearing. So overall output falls because of the decline in productivity and the resultant fall in labor employed, much like how declines in productivity has multiplier effects in the neoclassical growth model.

12 Model Extension: Changes on the extensive margin

In this appendix, I show how to endogenize movements in $\sigma_Q, \log A$ as well as changes in $\sigma_R, \rho QR$. I now assume that if firms are sufficiently unproductive, they are excluded from production by banks who prefer to lend into the interbank market. Previously, my assumption on the bank’s lending policy implied that even if $r_{fi} < r_b$, banks would still lend some fraction of their resources to firms on their island. Now I instead assume that if $r_{fi} < r_b$, then $b_i = -N$. Hence, firms with productivity $A_i < \bar{A}$ do not produce because they have no resources to hire labor. There is an implicit relationship between $r_b, \bar{A}$ given by

$$Nr_b = \bar{A} \frac{1}{\psi} L$$

(23)

where I have used the fact that $w = \frac{N}{L}$ assuming banks do not collect deposits. Now interbank clearing implies that

$$\tilde{r}_f - r_b \omega - r_b = \Phi \left( \frac{1}{\psi} \log \bar{A} \right)$$

(24)

where $\tilde{r}_f = \int_A^\infty r_f d\Phi(\log A_i)$ as before. The difference now is that there is a wedge between $\tilde{r}_f$ and $r_b$ related to the fact that there is a supply of capital from banks on bad islands. For firms with
productivity $A_i \geq \bar{A}$, loan market clearing implies that

$$w^{1-\psi}L A_i^{\psi-1}r_f^\psi = N \left( 1 + \frac{r_f \bar{A} - r_b}{\omega} \right)$$

I will approximate the solution to this expression like before with a log linear relationship between $A_i, r_f$. I will approximate around $\hat{A}$ implicitly defined as

$$w^{1-\psi}L A_r^{\psi-1}r_f^\psi = N \left( 1 + \hat{r}_f - r_b \right)$$

(25)

This is the level of productivity for which the interest rate charged on the island is equal to the average interest rate across islands. As before, I can now write under this approximation,

$$r_f = \tilde{r}_f \left( \frac{A_i}{\hat{A}} \right)^{\rho QR}$$

where $\rho QR$ is the derivative of the loan market clearing expression evaluated at $\hat{A}$

$$\rho QR = \frac{\psi - 1}{\psi + A_i^{\psi+1}(N\tilde{r}_f)^{\psi+1}/L^{\psi+1}\omega}$$

Substituting this expression into the definition of $\tilde{r}_f$, I have

$$\hat{A} = \left[ \int_{\hat{A}}^\infty A_i^{\rho QR} d\Phi(\log A_i) \right]^{1/\rho QR}$$

(26)

I now have unknowns $\tilde{r}_f, \hat{A}, \bar{A}, r_b$ and equations 26, 25, 24, and 23 as well as the definition of $\rho QR$. For illustrative purposes, I will consider the case where $\sigma_A = 1$ and $N = L$. Then the system of
equations defining the solution is given by

\[
\begin{align*}
\frac{\tilde{r}_f - r_b}{\omega - r_b} &= \Phi \left( \frac{\psi - 1}{\psi} \log \hat{A} \right) \\
1 + \frac{\tilde{r}_f - r_b}{\omega} &= \hat{A}^{\frac{\psi - 1}{\psi}} \tilde{r}_f \\
\log \hat{A} &= \frac{1}{2} \rho_{QR} + \frac{1}{\rho_{QR}} \log \Phi \left( \rho_{QR} - \frac{\psi - 1 \log r_b}{\psi} \right) \\
\rho_{QR} &= \frac{\psi - 1}{\psi + \frac{\hat{A}^{1-\psi} \tilde{r}_f}{\varphi}} \\
r_b &= \hat{A}^{\frac{\psi - 1}{\psi}}
\end{align*}
\]

In contrast to the basic case, these equations cannot be written solely in terms of \( N r_b \) and \( N \tilde{r}_f \). This implies that shocks to \( N \) do have effects on productivity. The key difference here is that capital levels affect the extensive margin and changes to that margin are not neutral with regards to misallocation.

What is interesting under this specification is that there are endogenous movements not only in \( \rho_{QR}, \sigma_R \) but also \( \sigma_Q \) and \( \log A \). In particular, it will now be the case that with a slight abuse of notation,

\[
\log A = \mathbb{E}[\log A_i | A_i > \bar{A}] = \frac{\sigma_A \phi (\log \bar{A})}{1 - \Phi (\log \bar{A})}
\]

\[
\sigma_A^2 = \text{Var}(\log A_i | A_i > \bar{A}) = \left[ 1 - \left( \frac{\phi (\log \bar{A})}{1 - \Phi (\log \bar{A})} \right)^2 \right]
\]

These are simply the formulas for the first and second moments of truncated normals. It will still be that \( \sigma_R \propto \sigma_{\tilde{r}_f} \) and approximately

\[
\log TFP = \log A + \frac{\psi - 1}{2} \sigma_A^2 - \frac{\psi}{2} \sigma_R^2 - \rho_{QR}(\psi - 1) \sigma_A \sigma_R
\]

Therefore, shocks to the marginal cost of leverage \( \omega \) will generate endogenous movements in all of these moments and productivity. It is difficult to get analytical results for the effect of shocks to \( \omega \). I simulate the model in Figure 17 varying \( \omega \) over a range fixing \( \psi = 4 \). As in the basic setup, increases in \( \omega \) lead to increases in \( \rho_{QR} \) and \( \sigma_R \). Note that the overall effect on productivity from these shifts are somewhat mitigated by the fact that \( \sigma_A \) also increases. On the other hand, the
mean plant-level productivity also falls dragging down the overall industry average.

The logic for the changes in $\sigma_R, \rho_{QR}$ are the same as the model with no extensive margin conditional on a fixed $\bar{A}$. The question then is why this cutoff falls with $\omega$ with knockon effects for $\sigma_A$ and $\log A$. The key is that $r_b$ falls with $\omega$. This reflects decreased demand for funds through the interbank market with the borrowing banks unwilling to take on the marginal dollar of leverage. Because demand for funds is lower, this leads banks with marginal projects to lend to the firms on their island instead of lending to the interbank market. Business cycles driven by this type of shock would not experience “cleansing” during recessions (Caballero and Hammour, 1994) though the reason is distinct from those sketched out in either Kehrig (2011) or Barlevy (2002).

At least for the calibration I consider, shocks to $\omega$ have similar effects as the baseline model. Figure 17 displays the comparative statics results varying $\omega$. Not only do the measures of misallocation increase but also the average productivity declines. At the same time, these shifts are partially compensated for by an increase in the dispersion of physical productivity. The fact that both productivity dispersion measures increase fits the data well. What is interesting to note is that shocks to bank capital can have both positive and negative effects on the productivity threshold $\bar{A}$. For very low levels of capital, the cutoff is increasing and then decreasing for sufficiently high levels of capital.

References


Board of Governors of the Federal Reserve System (1941). *Banking and Monetary Statistics 1914-1941*.


Richardson, G. (2007). The check is in the mail: Correspondent clearing and the collapse of the banking system, 1930 to 1933. *Journal of Economic History* 67, 643–671.


Figure 1: From Cole and Ohanian (2000) and Amaral and MacGee (2002). Deviation from a linear trend.
Figure 2: Data for all banks disaggregated to the state-level from various volumes of the Report of the Comptroller of the Currency. All variables have been normalized to their 1926 value.
CENSUS OF MANUFACTURES, 1931
REQUPIRED BY ACT OF CONGRESS APPROVED JUNE 18, 1929
ICE, MANUFACTURED

Under the law, no one not a sworn employee of the Bureau of the Census will be permitted to examine your report, and no information can or will be given out by the Bureau of the Census to any person outside that Bureau whether in Government or in private life, which would disclose, exactly or approximately, any of the facts or figures in your report.

GENERAL INSTRUCTIONS.—Reports are required for all plants. Separate reports are required for plants in different counties and for those in different cities having 10,000 inhabitants or more. A combined report may be made for two or more plants engaged in the same line of manufacture and located in the same city, town, borough, or village, or for two or more such plants located in the same county but in different cities, towns, boroughs, or villages having fewer than 10,000 inhabitants. The name and location of each plant must be given. DATA FOR MANUFACTURING AND OTHER NON-MANUFACTURING ACTIVITIES SHOULD BE OMITTED.

Answer all the inquiries in detail, supplying estimates if records are not available. The explanations should be read carefully before the inquiries are answered.

1. DESCRIPTION OF PLANT.—If this report covers more than one plant, give name and location of each, under “Remarks.”
   a. Name of Plant... Nelson Ice Company
   b. Name of Owner or Operator... G. H. Nelson
   c. Post-office Address of General Office... Stockton, Ala.

   LOCATION OF PLANT
   d. State... Alabama
   e. City, town, or village... Stockton
   f. County... Baldwin
   g. Street and Number... Stockton, Ala.

   i. Is plant located within present corporate boundaries of City, town, or Village? (Yes or No)... No
   j. Is this plant a branch or subsidiary of some other concern? (Yes or No)... Yes
   k. If so, give name and address of such concern...

   If not, name township, borough, or other civil division in which plant is located...

   l. Is this plant a branch or subsidiary of some other concern? (Yes or No)... Yes
   m. If so, give name and address of such concern...

   n. Place a check mark (✓) in proper space if, since January 1, 1930, this plant has changed its name...

   o. Location... Ownership... General nature of business... If so, give former name, location, ownership, or nature of business...

2. CHARACTER OF INDUSTRY.—These answers should be as definite as possible in brief space, indicating specific products and materials. Return with the schedule a card, a catalogue, or other printed matter ordinarily used by the concern to show the nature of its business.
   a. Products...
   b. Materials used...

3. PERIOD COVERED.—This report should relate preferably to the calendar year 1931, but it may be made to cover the business or fiscal year ending within the period from April 1, 1931, to March 31, 1932. It should, in either case, cover a full year’s operation, unless the plant was newly organized or went out of business within the year.

   The fiscal year or period covered by the information given below begins... 1931

4. TIME IN OPERATION AND HOURS OF LABOR:
   a. Number of days plant was operated during period covered...
   b. Normal number of hours per week for the individual wage earner...
   c. Does number of hours (b) refer to a 5-day, a 6½-day, or a 5½-day week, or to some other basis (specify)?...

Figure 3: Example of first page of census schedule.
Figure 4: Dynamics of industry, efficient, and plant-level productivity for cement.
Figure 5: Dynamics of industry, efficient, and plant-level productivity for manufactured ice.
Figure 6: Fraction of productivity decline from 1929 explained by changes in misallocation for cement varying $\sigma$. 
Figure 7: Fraction of productivity decline from 1929 explained by changes in misallocation for ice varying $\sigma$. 
Figure 8: Dynamics of $\sigma_R$ and $\rho_{QR}$ for cement industry. Changes in correlation is in levels. For standard deviations in logs.
Figure 9: Dynamics of $\sigma_R$ and $\rho_{QR}$ for ice industry. Changes in correlation is in levels. For standard deviations in logs.
Figure 10: Dynamics of $\sigma_R$ and $\rho_{QR}$ for macaroni industry. Because of data limitations, this is only for labor productivity not TFP. Changes in correlation is in levels. For standard deviations in logs.
Figure 11: Results for cement varying $\psi$ with 1% cut. This is fraction of decline from 1929 to given year.
Figure 12: Results for cement varying $\psi$ with 3% cut. This is fraction of decline from 1929 to given year.
Figure 13: Results for ice varying $\psi$ with 1% cut. This is fraction of decline from 1929 to given year.
Figure 14: Results for ice varying $\psi$ with 1% cut. This is fraction of decline from 1929 to given year.
Figure 15: Standard deviation and IQR of state-level lending rates from Bodenhorn (1995) normalized to 1929 value. The 1% tails have been trimmed from each year.
Figure 16: Effect of $\phi$ on steady state values with no extensive margin.
Figure 17: Effect of $\phi$ on steady state values with extensive margin.
<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>.024***</td>
<td>.016***</td>
<td>.025*</td>
<td>.017*</td>
</tr>
<tr>
<td></td>
<td>(.007)</td>
<td>(.005)</td>
<td>(.015)</td>
<td>(.009)</td>
</tr>
<tr>
<td>Log Wage</td>
<td>.088***</td>
<td>.085***</td>
<td>.088***</td>
<td>.086***</td>
</tr>
<tr>
<td></td>
<td>(.01)</td>
<td>(.01)</td>
<td>(.016)</td>
<td>(.016)</td>
</tr>
<tr>
<td>Plant effects</td>
<td>Random</td>
<td>Random</td>
<td>Fixed</td>
<td>Fixed</td>
</tr>
<tr>
<td>Year effects?</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

Table 1: Regression of deviations in $TFPR$ on state-level lending rates from Bodenhorn (1995). Log wage is deviation from industry-year average. The regressions exclude observations from 1933. Standard errors are clustered at the plant-level. *** significant at 1% level. ** significant at 5% level. * significant at 10% level.
<table>
<thead>
<tr>
<th></th>
<th>$R^2$ State * Industry</th>
<th>$R^2$ State Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1929</td>
<td>.07</td>
<td>.06</td>
</tr>
<tr>
<td>1931</td>
<td>.12*</td>
<td>.07</td>
</tr>
<tr>
<td>1935</td>
<td>.07</td>
<td>.04**</td>
</tr>
</tbody>
</table>

Table 2: $R^2$ of regression of $TFPR$ on state by industry interactions and another regression on solely state dummies for each year. * denotes reject the hypothesis that $R^2$ in 1929 is equal to $R^2$ in other given year at 10% level. ** at 5% level. I use a bootstrap procedure to calculate these values with 500 repetitions.

<table>
<thead>
<tr>
<th></th>
<th>$TFPR$ (1)</th>
<th>$TFPR$ (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Bank Leverage</td>
<td>.04</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>(.09)</td>
<td>(.07)</td>
</tr>
<tr>
<td>Log Bank Leverage 1931</td>
<td>.12**</td>
<td>.13 ***</td>
</tr>
<tr>
<td></td>
<td>(.05)</td>
<td>(.04)</td>
</tr>
<tr>
<td>Log Bank Leverage 1935</td>
<td>.07</td>
<td>.11**</td>
</tr>
<tr>
<td></td>
<td>(.07)</td>
<td>(.05)</td>
</tr>
<tr>
<td>Plant effects?</td>
<td>Fixed</td>
<td>Random</td>
</tr>
</tbody>
</table>

Table 3: Regression of deviations in $TFPR$ on state-level log leverage ratios. The regressions exclude observations in 1933. All regressions include year fixed effects. Standard errors are clustered at the plant-level. *** significant at 1% level. ** significant at 5% level. * significant at 10% level.
Table 4: Probits for exit on LFPR and LFPQ for the two industries. I do not include both TFPR and TFPQ simultaneously, because of multi-collinearity issues. 2% tails of TFPR and TFPQ are trimmed. All regressions include year and state fixed effects. Robust standard errors are reported in parentheses and and marginal effects calculated at the means are reported in italics. * denotes significance at the 10% level. ** denotes significance at the 5% level. *** denotes significance at the 1% level.

<table>
<thead>
<tr>
<th></th>
<th>Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFPR</td>
<td>-.18* -.16</td>
</tr>
<tr>
<td></td>
<td>(.10) (.11)</td>
</tr>
<tr>
<td></td>
<td>-.07 -.06</td>
</tr>
<tr>
<td>TFPQ</td>
<td>- - -.21** -.18**</td>
</tr>
<tr>
<td></td>
<td>(.09) (.07)</td>
</tr>
<tr>
<td></td>
<td>-.08 -.07</td>
</tr>
<tr>
<td>Industry effects?</td>
<td>YES NO YES NO</td>
</tr>
</tbody>
</table>

Table 5: Biannual Autocorrelations for a variety of plant-level variables for the two industries. TFPR, TFPQ are revenue and physical productivity demeaned by industry average. They are only labor productivity for the macaroni plants. Price is also demeaned by industry year average. As before the 2% tails of productivity distribution are trimmed before estimation. Each regression includes year, industry, and state fixed effects. Standard errors are clustered at the plant-level and calculated using the delta method. * denotes significance at the 10% level. ** denotes significance at the 5% level. *** denotes significance at the 1% level.

<table>
<thead>
<tr>
<th></th>
<th>TFPR</th>
<th>TFPQ</th>
<th>Log Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lag</td>
<td>.68***</td>
<td>.76***</td>
<td>.73***</td>
</tr>
<tr>
<td></td>
<td>(.03)</td>
<td>(.03)</td>
<td>(.03)</td>
</tr>
<tr>
<td>R²</td>
<td>.31</td>
<td>.46</td>
<td>.95</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Comment</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>.99</td>
<td>Standard discount rate.</td>
<td></td>
</tr>
<tr>
<td>σ</td>
<td>4</td>
<td>Elasticity of substitution used in empirical work.</td>
<td></td>
</tr>
<tr>
<td>π</td>
<td>.33</td>
<td>Frisch elasticity of labor supply from Gertler and Kiyotaki (2010).</td>
<td></td>
</tr>
<tr>
<td>ω</td>
<td>20</td>
<td>Chosen to target initial steady state of $\frac{N}{wL} = .09$.</td>
<td></td>
</tr>
<tr>
<td>ν</td>
<td>5.584</td>
<td>From Gertler and Kiyotaki (2010).</td>
<td></td>
</tr>
<tr>
<td>σ&lt;sub&gt;A&lt;/sub&gt;</td>
<td>.25</td>
<td>Match ratio of productivity dispersion from Foster et al. (2008).</td>
<td></td>
</tr>
<tr>
<td>ξ</td>
<td>.003</td>
<td>Transfer to entering bankers. Similar to Gertler and Kiyotaki (2010).</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>-6</td>
<td>Normalization.</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Parameter values for baseline model.