

# AN ESTIMATED STRUCTURAL MODEL OF ENTREPRENEURIAL BEHAVIOR

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## Abstract

Using a rich panel of data from New York dairy farms, we construct and estimate a dynamic model of entrepreneurial behavior. Farmers face uninsured risks, borrowing limits and liquidation costs. We allow for occupational choice, renegotiation and retirement. We estimate the model via simulated minimum distance, matching both the production and the financial sides of the data. Our model fits the data well in the aggregate and in the cross section. Policy experiments indicate that financial factors play an important role. Farms with high productivity appear to be more constrained than those whose productivity is low. Short-term liquidity constraints inhibit the accumulation of capital and assets. Allowing farms to renegotiate debt allows productive farms to continue operations. Liquidation costs are large, implying that their removal could be socially beneficial. The non-pecuniary benefits of farming appear to be large, and have significant effects on farm behavior.

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# 1 Introduction

Entrepreneurs have long been recognized as a crucial force in the economy. As exemplified in Schumpeter’s theory of creative destruction, entrepreneurs are considered to be engines of innovation and economic growth.<sup>1</sup> Another strand of the literature on entrepreneurs focuses on their position in the wealth distribution and their role in wealth creation (Quadrini 2000, 2009, Cagetti and De Nardi 2006). In these studies, entrepreneurs amass wealth because they utilize unique production technologies, and because they reinvest their income in their own businesses.

Identifying the influence of financial constraints is often considered key to understanding entrepreneurial decisions and their implications for investment and growth.<sup>2</sup> In this paper, we formulate and estimate a dynamic structural model of entrepreneurial behavior, using detailed production and financial data from a panel of owner-operated New York State dairy farms. We use the model to identify the financial constraints facing entrepreneurs, and to quantify their importance for asset accumulation, borrowing, and exit.

Many analyses of entrepreneurial behavior also emphasize non-pecuniary considerations. Moskowitz and Vissing-Jørgensen (2002) find that the returns entrepreneurs earn on their undiversified and risky investments are no greater than the returns on public equities. Hamilton (2000) finds that self-employment typically results in lower earnings. Both findings suggest that entrepreneurs receive non-pecuniary benefits. Vereshchagina and Hopenhayn (2009) note, however, that entrepreneurs operate in a financial environment that can encourage risky investment even in the absence of a return premium.<sup>3</sup> Our model contains features that allow for both mechanisms, which are by no means mutually exclusive. Occupational choice and limited liability encourage risk-taking, while non-pecuniary benefits and liquidation costs discourage it. We use the model to assess the strength of each mechanism.

Our data are unusually well-suited for these tasks. They contain information on both real and financial activities, including input use, output and revenue, investment, borrowing and equity.<sup>4</sup> The farms in our data face substantial uninsured risk. Since they

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<sup>1</sup>Caree and Thurik (2003) provide an extended literature review, while Wong, Ho and Autio (2005) include a review of recent empirical work. Also see Quadrini (2009) and Decker et al. (2014).

<sup>2</sup>Surveys of this literature appear in Parker (2005), Quadrini (2009) and Carreira and Silva (2010).

<sup>3</sup>This builds on earlier work on occupational choice by Kihlstrom and Laffont (1979), where risk loving individuals become entrepreneurs and risk averse ones prefer to be workers.

<sup>4</sup>Most plant-level datasets contain detailed information on real activity such as input use and investment at a nationally representative level, but do not cover financial variables. On the other hand, datasets with detailed financial information, such as COMPUSTAT, focus on publicly traded companies, and do

are drawn from a single region and industry, they are less vulnerable to issues of unobserved heterogeneity. Our panel spans a decade, which allows us to measure farm-level fixed effects, and sharpens the identification of the model’s dynamic mechanisms. We are therefore able to disentangle the effects of real and financial factors on the operating decisions of firms, a classic problem in economics.<sup>5</sup> By allowing us to measure the risk and returns to dairy farming, our data also allows us to estimate the non-pecuniary value of being a dairy farmer.

While structural models of entrepreneurship have been estimated with firm-level data for developing countries, many using Townsend’s Thai data,<sup>6</sup> a lack of data has hindered the estimation of similar models for developed countries. The structural models of Buera (2009) and Evans and Jovanovic (1989) focus on the decision to become an entrepreneur, rather than the behavior of established businesses. Our paper fills this niche. Although the farms in our data are substantial enterprises, with an average of almost 3 million dollars in assets, and use increasingly sophisticated technology (McKinley 2014), they are almost all run by one or two operators. Our paper is thus a useful complement to the structural corporate finance literature, where dynamic models with explicit financial constraints are fit to data for corporations (Pratap and Rendon 2003, Hennessey and Whited 2007, Strebulaev and Whited 2012). The paper arguably most similar to ours is Herranz et al. (2008), who match the unconditional cross-sectional distribution of owner equity and assets in the Survey of Small Business Finance. Our detailed panel dataset allows us to develop a much richer model, and to estimate it by matching disaggregated trajectories through time.

We begin our analysis with a description of our data. Using production parameters estimated from our structural model, we construct a measure of total factor productivity, which we decompose into a permanent farm-specific component, transitory idiosyncratic shocks, and transitory aggregate shocks. We find that high-productivity farms (as measured by the permanent farm-specific component) operate at much larger scales, invest

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not provide information on family- or single entrepreneur-operated firms.

<sup>5</sup>This question lies at the heart of the voluminous, and often contentious literature on investment-cash flow regressions. Fazzari, Hubbard and Peterson (1988), who kick off this literature, find that financial constraints are important in determining investment. Kaplan and Zingales (1997) is the most prominent study to argue that the investment-cash flow relationship reflects expected future returns. Bushman et al. (2011) contains a review. Of note for our purposes are Bierlen and Featherstone (1998), who perform cash flow regressions on a dataset of Kansas farms. Studies using simulated data from structural models to analyse the performance of these regressions include Gomes (2001), Pratap (2003) and Moyen (2004).

<sup>6</sup>These data are described in Townsend et al. (1997) and Samphantharak and Townsend (2010). A recent study especially relevant to the project at hand is Karaivanov and Townsend (2014), which also contains a literature review.

more and pay down their debt at faster rates than low productivity farms. We also calculate the static optimal capital stock for a frictionless environment, and find that high productivity farms operate further below this optimal scale. This justifies their higher investment rates and suggests that financial constraints may be important in explaining their distance from the optimum. In this respect, our work is similar in spirit to studies assessing the allocation of resources across firms, such as Hsieh and Klenow (2009), Jeong and Townsend (2007), Buera, Kaboski and Shin (2011), Midrigan and Xu (2014).

Our measure of aggregate productivity correlates closely with changes in the price of milk. We find that times of higher aggregate productivity are also times of higher investment. Because aggregate productivity appears to be serially uncorrelated, this suggests that cash flow directly affects investment. We find that cash flow and investment are indeed positively correlated with each other, controlling for productivity.

We then move to the model. Risk-averse farmers face uninsured risks, borrowing limits arising from limited commitment and liquidation costs, and working capital/liquidity constraints. Older farmers retire, and farmers of any age can exit the industry. A key feature of our financial environment is that it allows for the renegotiation of debt. This is consistent with actual practice, which shows that many farms declaring bankruptcy reorganize rather than liquidate (Stam and Dixon, 2004). Another key feature is that farms must purchase intermediate goods before their productivity shocks are fully realized, exposing them to significant financial risk. We estimate the model using a form of simulated minimum distance, matching both the production and the financial sides of the data.

Uncovering the deep parameters of the model allows us to perform policy experiments to assess the importance of each constraint. We find that these constraints play an important role in determining farm outcomes. Relaxing the short-term borrowing limit on the purchase of variable inputs generates substantial increases in the capital stock, assets and output of the average farm. The ability to renegotiate their debt allows productive farms to continue operating despite temporary setbacks. Finally we find the deadweight costs of farm liquidation to be quite large, about 40 percent of total assets. Eliminating them would provide an important social benefit.

Our estimates imply that non-pecuniary benefits play a significant role in discouraging exit from farming, especially in their interaction with financial constraints. For example, although liquidation costs are not quantitatively important in determining farm dynamics when non-pecuniary benefits are present, in the absence of these benefits liquidation costs would discourage many low-performing farms from shutting down.

We also find that our model can account for several aspects of the cross sectional variation in the data. Regressions on model-simulated data show that high net worth farms appear to allocate their resources more productively, reflecting a greater ability to finance variable inputs. Farms with high cash flow have larger investment rates, as observed in the data.

The rest of the paper is organized as follows. In section 2 we introduce our data and perform some diagnostic exercises. In section 3 we construct the model. In section 4 we describe our estimation procedure. In section 5 we present parameter estimates and assess the model's fit. In section 6 we perform a number of numerical exercises, designed to quantify the effects of financial constraints. We conclude in section 7.

## 2 Data and Descriptive Analysis

### 2.1 The DFBS

The Dairy Farm Business Survey (DFBS) is an annual survey of New York dairy farms conducted by Cornell University. The data include detailed financial records of revenues, expenses, assets and liabilities. Physical measures such as acreage and herd sizes are also collected. Assets are recorded at market as well as book value. The data allow for the construction of income statements, balance sheets, cash flow statements, and a variety of productivity and financial measures (Cornell Cooperative Extension, 2006; Karzes et al., 2013). Participants can then compare their management practices to those of their peers. These diagnoses are an important benefit of participation, which is voluntary (Cornell Cooperative Extension, 2015). Given such considerations, the DFBS data are not representative,<sup>7</sup> but they are probably of high quality.

Our dataset is an extract of the DFBS covering calendar years 2001-2011. This is an unbalanced panel containing 541 distinct farms, with approximately 200 farms surveyed each year. We trim the top and bottom 2.5% of the size distribution; the remaining farms have time-averaged herd sizes ranging between 34 and 1,268 cows. Since our model is explicitly dynamic, we also eliminate farms with observations for only one year. Finally

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<sup>7</sup>Farms in our sample have larger revenues and herd sizes than the average New York State dairy farm. In 2011, average revenue in our sample was \$2,285,000, compared to the state average of \$520,000. In the same year, the average herd size of New York State dairy farms was 209 cows, while our sample had an average herd size of 403. In demographic terms the sample is very similar to state averages: the principal operator statewide has an average age of 51, as in our sample. All the farms in our sample are family-owned, as are virtually all (97 percent) of the dairy farms in New York state. (New York State Department of Agriculture and Markets 2012).

we eliminate farms for which there is no information on the age of the operators. Since these are family-operated farms, we would expect retirement considerations to influence both production and finance decisions. These filters leave us with a final sample of 338 farms and 2,037 observations. During the same period, the number of dairy farms in New York State fell from 7,180 to 5,240 (New York State Department of Agriculture and Markets, 2012), so that our sample contains roughly 5 percent of the total.

Table 1 shows summary statistics. The median farm is operated by two operators and more than 80 percent of the farms have two or fewer operators. The average age of the main operator is 51 years. For multi-operator farms, however, the relevant time horizon for investment decisions is the age of the youngest operator, who will likely become the primary operator in the future. On average, the youngest operator tends to be about 8 years younger than the main operator. In our analysis we will consider the age of the youngest operator as the relevant one for age-sensitive decisions.

Table 1 also illustrates that these are substantial enterprises: the yearly revenues of the average farm are in the neighborhood of 1.5 million dollars in 2011 terms. The distribution of revenues is heavily skewed to the left, with median farm revenues equal to about half the mean. For more than 80 percent of farm-year observations, farm revenues are under 2 million dollars. A large part of farm expenses are accounted for by what we term variable inputs: intermediate goods and hired labor. Of these labor expenses are relatively small, on average about 14 percent of all expenditures on variable inputs. The remainder is accounted for by intermediate goods such as feed, fertilizer, seed, pest control, repairs, utilities, insurance etc. We also report the amounts spent on capital leases and interest, which are less than 10 percent of total expenditures on average.

Capital stock consists of machinery, real estate (including land and buildings) and livestock, of which real estate is the most valuable. Most of the capital stock is owned, but the median farm leases about 14 percent of its capital.<sup>8</sup> Real estate is the most intensively leased form of capital. The majority of farms lease less than 20 percent of their machinery and equipment. Livestock is almost always owned. Capital is by far the predominant asset, accounting for more than 80 percent of farm assets.

Farm liabilities include accounts payable, debt, and financial leases on equipment and structures. For the median farm, this accounts for about 70 percent of total liabilities. Deferred taxes constitute the remainder. Combining total assets and liabilities reveals that the average farm has a net worth of 1.4 million dollars. Only 28 (or 1.4 percent) of

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<sup>8</sup>We construct leased capital by dividing leasing expenses by the user cost ( $r + \delta - \omega$ ), where  $r = 0.04$  is the real interest rate, and  $\delta$  and  $\omega$  are depreciation and appreciation rates, respectively. We construct separate user costs for each of three capital types.

Variable	Standard				
	Mean	Median	Deviation	Maximum	Minimum
No. of Operators	1.82	2	0.93	6	1
Operator 1 Age	51.04	51	10.68	87	16
Youngest Operator Age	43.04	43	10.60	74	12
Herd Size (Cows)	302	169	286	1,268	34
Total Capital	2,793	1,802	2,658	15,849	212
Machinery	654	446	606	4,164	13
Real Estate	1,443	924	1,451	10,056	0
Livestock	696	394	700	5,215	39
Owned Capital	2,267	1,496	2,132	14,286	83
Machinery	490	331	461	2,895	3
Real Estate	1,097	710	1,103	9,100	0
Livestock	680	390	674	3,467	39
Owned/Total capital	0.84	0.86	0.12	1.00	0.26
Revenues	1,417	726	1,490	8,043	68
Total Expenses	1,199	608	1,278	6,296	57
Variable Inputs	1,098	553	1,177	5,846	55
Leasing and Interest	101	52	120	1,026	0
Total Assets	2,707	1,738	2,565	16,134	103
Total Liabilities	1,302	710	1,346	7,560	0
Net Worth	1,404	824	1,597	12,951	-734

Notes: Financial variables are expressed in thousands of 2011 dollars

Table 1: Summary Statistics from the DFBS

Variable	Gross Investment / Owned Capital	Cooper- Haltiwanger LRD
Average investment rate	0.086	0.122
Inaction rate (< abs(0.01))	0.097	0.081
Fraction of observations < 0	0.087	0.104
Positive spike rate (>0.2)	0.074	0.186
Negative spike rate (<-0.2)	0.002	0.018
Serial correlation	0.097	0.058

Table 2: Investment Rates

all farm-years report negative net worth.

The DFBS reports net investment for each type of capital. It also reports depreciation, allowing us to construct a measure of gross investment. Following the literature, we will focus on investment rates, scaling investment by the market value of owned capital at the beginning of each period. Table 2 describes the distribution of investment rates. Cooper and Haltiwanger (2006) show, using data from the Longitudinal Research Database (LRD), that plant-level investment often occurs in large increments, suggesting a prominent role for fixed investment costs. Table 2 shows statistics comparable to theirs and, for reference, reproduces the statistics for gross investment rates shown in their Table 1. Relative to the LRD, investment spikes are much less frequent in the DFBS. The average investment rate is also a bit lower, and the inaction rate is slightly higher. These suggest that fixed investment costs are less important in the DFBS, and in the interest of tractability we omit them from our structural model.

## 2.2 Productivity

### 2.2.1 Our Productivity Measure

One of the strengths of the DFBS data is that it allows us to estimate each farm’s productivity. We assume that farms share the following Cobb-Douglas production function

$$Y_{it} = z_{it} M_{it}^{\alpha} K_{it}^{\gamma} N_{it}^{1-\alpha-\gamma},$$

where we denote farm  $i$ ’s gross revenues at time  $t$  by  $Y_{it}$  and its entrepreneurial input, measured as the time-averaged number of operators by  $M_{it}$ .<sup>9</sup>  $K_{it}$  denotes the capital stock;  $N_{it}$  represents expenditure on all variable inputs, including hired labor and inter-

<sup>9</sup>More than two thirds of all farms and 90 percent of farm-years display no change in family size.

mediate goods; and  $z_{it}$  is a stochastic revenue shifter reflecting both idiosyncratic and systemic factors.<sup>10</sup> With the exception of operator labor, all inputs are measured in dollars. Although this implies that we are treating input prices as fixed, variations in these prices can enter our model through changes in the profit shifter  $z_{it}$ .

In per capita terms, we have

$$y_{it} = \frac{Y_{it}}{M_{it}} = z_{it} k_{it}^{\gamma} n_{it}^{1-\alpha-\gamma}.$$

In this formulation, returns to scale are  $1 - \alpha$ , with  $\alpha$  measuring an operator’s “span of control” (Lucas, 1978). Using the structural estimation procedure described below, we estimate  $\hat{\alpha}$  as 0.174 and  $\hat{\gamma} = 0.121$ . This allows us to calculate total factor productivity as

$$z_{it} = \frac{y_{it}}{k_{it}^{\hat{\gamma}} n_{it}^{1-\hat{\alpha}-\hat{\gamma}}}. \quad (1)$$

We assume that the resulting TFP measure can be decomposed into an individual fixed effect  $\mu_i$ , a time-specific component, common to all farms,  $\Delta_t$ , and an idiosyncratic i.i.d component  $\varepsilon_{it}$ :

$$\ln z_{it} = \mu_i + \Delta_t + \varepsilon_{it}. \quad (2)$$

We find that a Hausman test rejects a random effects specification. Regressing  $z_{it}$  on farm and time dummies yields estimates of all three components. The fixed effect is dispersed between 0.42 and 1.55, with a mean of 1.017 and a standard deviation of 0.19. There are therefore significant differences in time invariant productivity across farms. The time effect  $\Delta_t$  is constructed to be zero mean. This series is effectively uncorrelated,<sup>11</sup> and has a standard deviation of 0.061. The idiosyncratic residual  $\varepsilon_{it}$  can also be treated as uncorrelated (the serial correlation is 0.02), with a standard deviation of 0.069.

To provide some insight into this productivity measure, Figure 1 plots the aggregate component  $\Delta_t$  against real milk prices in New York State (New York State Department of

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<sup>10</sup>The assumption of decreasing returns to scale in non-management inputs is not inconsistent with the literature. Tauer and Mishra (2006) find slightly decreasing returns in the DFBS. They argue that while many studies find that costs decrease with farm size: “Increased size per se does not decrease costs—it is the factors associated with size that decrease costs. Two factors found to be statistically significant are efficiency and utilization of the milking facility.”

<sup>11</sup>It is often argued that milk prices follow a three-year cycle. Nicholson and Stephenson (2014) find a stochastic cycle lasting about 3.3 years. While Nicholson and Stephenson report that in recent years a “small number” of farmers appear to be planning for cycles, they also report (page 3) that: “the existence of a three-year cycle may be less well accepted among agricultural economists and many ... forecasts ... do not appear to account for cyclical price behavior. Often policy analyses ... assume that annual milk prices are identically and independently distributed[.]”

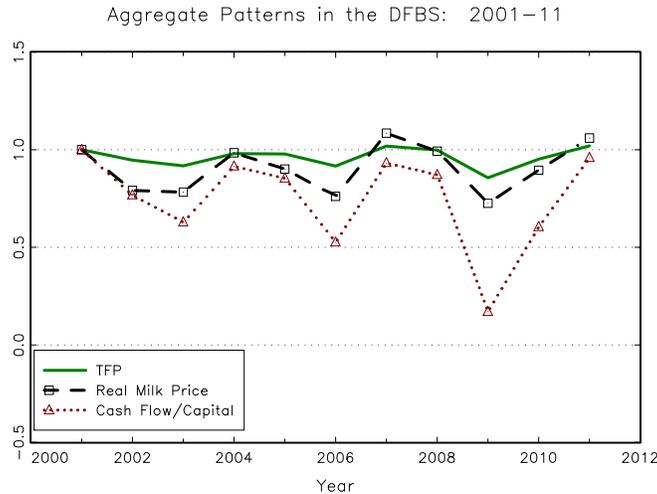


Figure 1: Aggregate TFP, real Milk Prices, and Cash Flow

Agriculture and Markets, 2012).<sup>12</sup> The aggregate component of TFP follows milk prices very closely – the correlation is well over 90% – which gives us confidence in our measure. On the same graph we plot the average value of the cash flow (net operating income less estimated taxes) to capital ratio. Aggregate cash flow is also closely related to our aggregate TFP measure. Cash flow varies quite significantly, indicating that farms face significant financial risk.

### 2.2.2 Productivity and Farm Characteristics: Descriptive Evidence

How are productivity and farm performance related? Figures 2 and 3 illustrate how farm characteristics vary as a function of the time-invariant component of productivity,  $\mu_i$ . We divide the sample into high- and low-productivity farms, splitting around the median value of  $\mu_i$ , and plot the evolution of several variables. To remove scale effects, we either express these variables as ratios, or divide them by the number of operators.

Our convention will be to use thick solid lines to represent high-productivity farms and the thinner dashed lines to represent low-productivity farms. Figure 2 shows output/revenues and input choices. The top two panels of this figure show that high-productivity farms operate at a scale 4-5 times larger than that of low-productivity

<sup>12</sup>Although the government intervenes extensively in the market for raw milk, much of the current regulation only imposes price floors, with actual prices varying according to market conditions. Manchester and Blaney (2001) provide a review.



Figure 2: Production and Inputs by TFP and Calendar Year

farms.<sup>13</sup> This size advantage is increasing over time: high productivity-firms are growing while low-productivity firms are static. The bottom left panel shows that high-productivity farms lease a larger fraction of their capital stock (18 percent vs. 8 percent). The leasing fractions are all small and stable, however, implying that farms expand primarily through investment.

The bottom right panel of Figure 2 shows that the ratio of variable inputs – feed, fertilizer, and hired labor – to capital is also higher for high productivity farms (40% vs. 30%). This is at odds with a simple Cobb-Douglas production function in a frictionless setting. However, financial constraints that impede the purchase of variable inputs may lead to higher variable input ratios for high productivity farms, if such farms have better access to funding. To account for this possibility, our model will allow for financial constraints on the purchase of inputs.

Figure 3 shows financial variables. The top two panels contain median cash flow

<sup>13</sup>Using the 2007 US census of agriculture, Adamopoulos and Restuccia (2014) document that farms with higher labor productivity are indeed substantially larger.

and gross investment. The two variables are positively correlated in the aggregate; for example, the recession of 2009 caused both of these variables to decline. Given that the aggregate shocks are not persistent, the correlation of cash flow and investment suggests financial constraints, which will be relaxed in periods of high output prices. The middle left panel shows investment as a fraction of owned capital, and confirms that high-productivity farms generally invest at higher rates. The middle right panel shows dividends, which are also correlated with cash flow. Dividend flows are in general quite modest, especially for low-productivity farms.

The bottom row of Figure 3 shows two sets of financial ratios. The left panel shows debt/asset ratios.<sup>14</sup> Although high-productivity farms begin the sample period with more debt, over the sample period they rapidly decrease their leverage. By 2011, high and low-productivity farms have fairly similar debt/asset ratios. This suggests that the high-TFP firms are using their profits to de-lever as well as to invest.

In a static frictionless model, the optimal capital stock for a farm with productivity level  $\mu_i$  is given by  $k_i^* = [\kappa \exp(\mu_i)]^\alpha$ , where  $\kappa$  is a positive constant.<sup>15</sup> The bottom right panel of Figure 3 plots median values of the ratio  $k_{it}/k_i^*$ , showing the extent to which farms are operating at their efficient scales. The median low-productivity farm is close to the optimal capital stock over the entire sample period. In contrast, the capital stocks of high-productivity farms are well below their optimal size, even as they grow rapidly. This suggests that financial constraints are hindering the efficient allocation of capital. Midrigan and Xu (2014) find that financial constraints impose their greatest distortions by limiting entry and technology adoption. To the extent that high-productivity farms are more likely to utilize new technologies, such as robotic milkers (McKinley, 2014), our results are consistent with their findings. Our results also comport with Buera, Kaboski and Shin's (2011) argument that financial constraints are most important for large-scale technologies.

### 2.2.3 Productivity and Farm Characteristics: Regression Evidence

To further explore what lies behind the variations in the  $n/k$  ratio, we construct a measure of distortions following Hsieh and Klenow (2009). The first order conditions of

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<sup>14</sup>To ensure consistency with the model, and in contrast to Table 1, we add capitalized values of leased capital to both assets and liabilities.

<sup>15</sup>This expression can be found by maximizing  $E(z_{it})k_{it}^\gamma n_{it}^{1-\alpha-\gamma} - n_{it} - (r + \delta - \varpi)k_{it}$ . In contrast to footnote 8, we use a single user cost for all capital. Standard calculations show that  $\kappa = \left(\frac{\gamma}{r+\delta-\varpi}\right)^{\alpha+\gamma} (1-\alpha-\gamma)^{1-\alpha-\gamma} E(\exp(\Delta_t \varepsilon_{it}))$ .

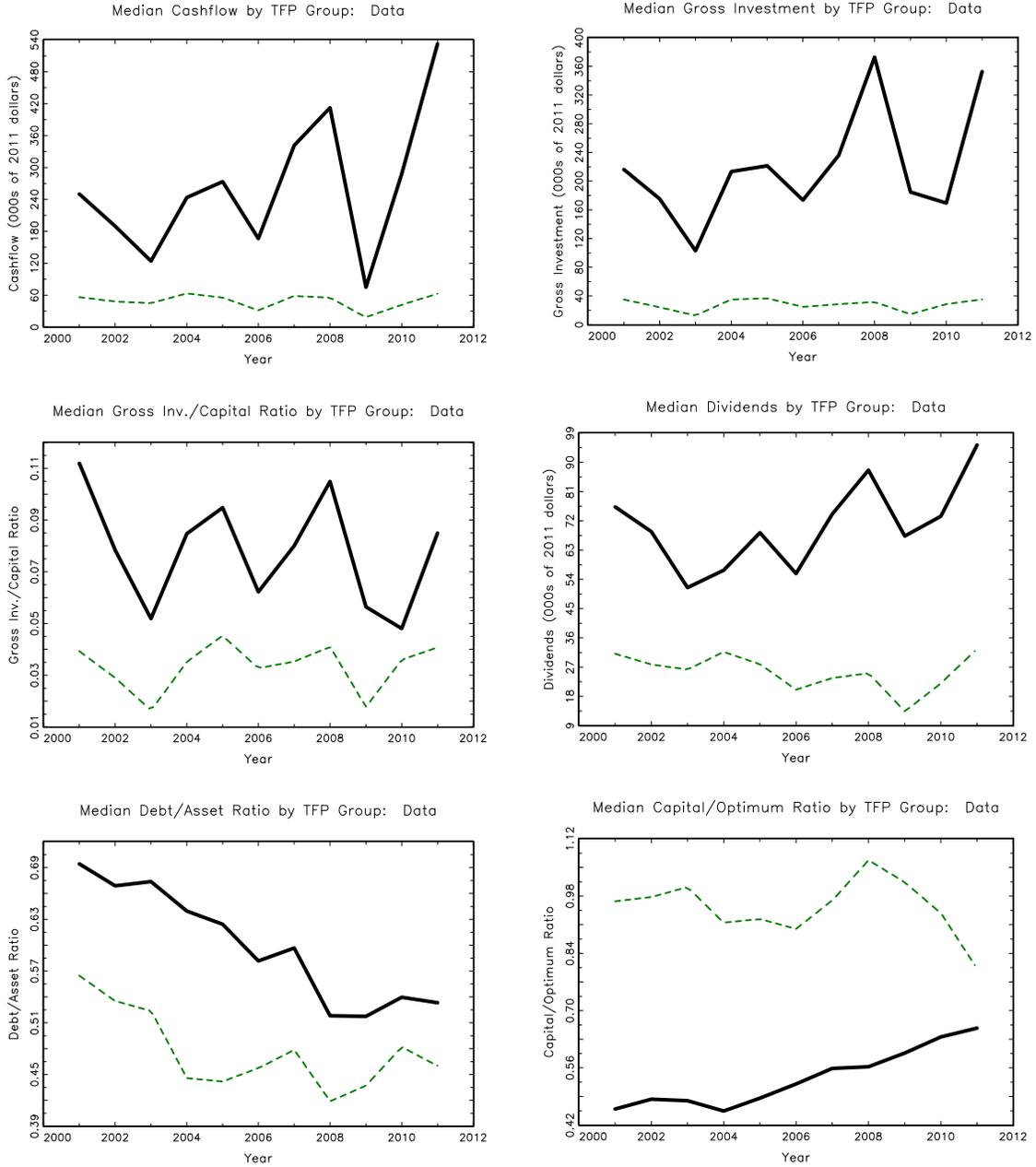


Figure 3: Investment and Finances by TFP and Calendar Year

	Standard				
	Mean	Median	Deviation	Maximum	Minimum
$\omega_{it}$	1.07	1.04	0.37	2.77	0.21
	Regression Coefficients: Dependent Variable $(\omega_{it} - 1)^2$				
	Coeff.	Std. Err	Coeff.	Std. Err	
$z_{it}$	0.112	0.059	0.046	0.059	
Total Assets	-0.076*	0.010			
Net Worth			-0.051*	0.013	
Individual Effects	Yes		Yes		
Time Dummies	Yes		Yes		

Table 3: Input Distortions

a static optimization problem imply that

$$\frac{n_{it}}{uc \cdot k_{it}} = \frac{1 - \alpha - \gamma}{\gamma},$$

$$\omega_{it} = \frac{n_{it}}{uc \cdot k_{it}} \frac{\gamma}{(1 - \alpha - \gamma)} = 1,$$

where:  $uc$  denotes the frictionless user cost of capital, based on a real interest rate of 4% and a depreciation rate (net of capital gains) calibrated from the data; and the price of variable inputs is normalized to 1. Any suboptimal input use (say as a result of a tax on a particular input) will result in a value of  $\omega$  different from 1.  $\omega_{it}$  is therefore a measure of the degree of distortion of input use, which will take values above (below) 1 if the farm uses a higher (lower)  $n/k$  ratio than that implied by the first order conditions of its optimization problem.

Table 3 shows that this measure has a mean of 1.07 and a median of 1.04, implying that the median farm uses a close to optimal proportion of variable inputs, given its capital stock. On the other hand, 50% of farms purchase less than the optimal amount. In the second panel of the table we consider how deviations from the optimal value of 1 are related to productivity and to financial variables. Interestingly, despite controlling for farm and time effects, financial variables play an important role in determining the degree to which the input mix is distorted. Asset rich farms have a greater ability to use inputs optimally. Farms with high net worth also use a relatively undistorted mix of inputs. These results suggest that financial variables play an important role in the production decisions of the farm. TFP does not have a significant effect, suggesting that the effect of

	Net Investment/ Owned Capital		Gross Investment/ Owned Capital	
	(1)	(2)	(3)	(4)
TFP ( $z_{it}$ )		-0.449*		-0.507*
		0.092		0.096
TFP $\mu_i$	0.029		0.084*	
	0.025		0.026	
Cash Flow/Capital	0.177*	0.977*	0.258*	1.140*
	0.085	0.173	0.089	0.182
Operator Age	-0.002*	-0.003	-0.002*	-0.005*
	0.000	0.002	0.000	0.002
Year Effects	Yes	Yes	Yes	Yes
Fixed Effects	No	Yes	No	Yes

Table 4: Investment-Cash Flow Regressions

TFP may be in creating better financial health for firms, which in turn allow it to use a closer to optimal input mix.

Next, we reconsider the empirical correlates of investment. In the standard investment regression, investment-capital ratios are regressed against a measure of Tobin's q and a measure of cash flow. While our farms are not publicly traded firms, and we cannot construct Tobin's q, we can use  $z_{it}$  or one of its components as a substitute. Table 4 reports the coefficient estimates. The first column of Table 4 shows that firms with higher values of the TFP fixed effect  $\mu_i$  have higher investment rates, although the effect is not statistically significant. Investment rates also decline with age, although the coefficient is small. This shows (weak) evidence of life cycle behavior on the part of the farmers. Cash flow is positively and significantly related to investment. . The results change once we introduce fixed effects in the second column. While the coefficient on cash flow is still positive and significant, TFP enters with a negative sign. The negative coefficients on TFP are more difficult to interpret, but the inclusion of time and fixed effects again means that the only independent component of  $z_{it}$  is  $\varepsilon_{it}$ . Using gross rather than net investment has little effect. Our results contrast to those of Weersink and Tauer (1989), who estimate investment models using DFBS data from 1973-1984. Weersink and Tauer find that investment levels are decreasing in cash flow and increasing in asset values (which proxy for profitability).

### 3 Model

Consider a farm family seeking to maximize expected lifetime utility at “age”  $q$ :

$$E_q \left( \sum_{h=q}^Q \beta^{h-q} [u(d_h) + \chi \cdot 1\{\text{farm operating}\}] + \beta^{Q-q+1} V_{Q+1}(a_{Q+1}) \right),$$

where:  $q$  denotes the age of the principal (youngest) operator;  $d_q$  denotes farm “dividends” per operator; the indicator  $1\{\text{farm operating}\}$  equals 1 if the family is operating a farm and 0 otherwise, and  $\chi$  measures the psychic/non-pecuniary gains from farming;  $Q$  denotes the retirement age of the principal operator;  $a$  denotes assets; and  $E_q(\cdot)$  denotes expectations conditioned on age- $q$  information. The family discounts future utility with the factor  $0 < \beta < 1$ . Time is measured in years. Consistent with the DFBS data, we assume that the number of family members/operators is constant. We further assume a unitary model, so that we can express the problem on a per-operator basis. To simplify notation, throughout this section we omit “ $i$ ” subscripts.

The flow utility function  $u(\cdot)$  and the retirement utility function  $V_{Q+1}(\cdot)$  are specialized as

$$\begin{aligned} u(d) &= \frac{1}{1-\nu} (c_0 + d)^{1-\nu}, \\ V_{Q+1}(a) &= \frac{1}{1-\nu} \theta \left( c_1 + \frac{a}{\theta} \right)^{1-\nu}, \end{aligned}$$

with  $\nu \geq 0$ ,  $c_0 \geq 0$ ,  $c_1 \geq c_0$  and  $\theta \geq 1$ . Given our focus on farmers’ business decisions, we do not explicitly model the farmers’ personal finances and saving decisions. We instead use the shift parameter  $c_0$  to capture a family’s ability to smooth variations in farm earnings through outside income, personal assets, and other mechanisms. The scaling parameter  $\theta$  reflects the notion that upon retirement, the family lives for  $\theta$  years and consumes the same amount each year.

Before retirement, farmers can either work for wages or operate a farm. While working for wages, the family’s budget constraint is

$$a_{q+1} = (1+r)a_q + w - d_q, \tag{3}$$

where:  $a_q$  denotes beginning-of-period financial assets;  $w$  denotes the age-invariant outside wage; and  $r$  denotes the real risk-free interest rate. Workers also face a standard borrowing

constraint:

$$a_{q+1} \geq 0.$$

Turning to operating farms, recall that gross revenues per operator follow

$$y_q = z_{qt} k_q^\gamma n_q^{1-\alpha-\gamma}, \quad (4)$$

where  $k_q$  denotes capital,  $n_q$  denotes variable inputs, and  $z_{qt}$  is a stochastic income shifter reflecting both idiosyncratic and systemic factors. These factors include weather and market prices, and are not fully known until after the farmer has committed to a production plan for the upcoming year. In particular, while the farm knows its permanent TFP component  $\mu$ , it makes its production decisions before observing the transitory effects  $\Delta_t$  and  $\varepsilon_q$ .

A farm that operated in period  $q - 1$  begins period  $q$  with debt  $b_q$  and assets  $\tilde{a}_q$ . As a matter of notation, we use  $b_q$  to denote the total amount owed at the beginning of age  $q$ :  $r_q$  is the contractual interest rate used to deflate this quantity when it is chosen at age  $q - 1$ . Expressing debt in this way simplifies the dynamic programming problem when interest rates are endogenous. At the beginning of period  $q$ , assets are the sum of undepreciated capital, cash, and operating profits:

$$\tilde{a}_q \equiv (1 - \delta + \varpi)k_{q-1} + \ell_{q-1} + y_{q-1} - n_{q-1}, \quad (5)$$

where:  $0 \leq \delta \leq 1$  is the depreciation rate;  $\varpi$  is the capital gains rate, assumed to be constant; and  $\ell_{q-1}$  denotes liquid (cash) assets, chosen in the previous period.

A family operating its own farm must decide each period whether to continue the business. The family has three options: continued operation, reorganization, or liquidation. If the family decides to continue operating, it will have two sources of funding: net worth,  $e_q \equiv \tilde{a}_q - b_q$ , and the time- $q$  value of new debt,  $b_{q+1}/(1 + r_{q+1})$ . (We assume that all debt is one-period.) It can spend these funds in three ways: purchasing capital; issuing dividends,  $d_q$ ; or maintaining its cash reserves:

$$e_q + \frac{b_{q+1}}{1 + r_{q+1}} = \tilde{a}_q - b_q + \frac{b_{q+1}}{1 + r_{q+1}} = k_q + d_q + \ell_q. \quad (6)$$

Combining the previous two equations yields

$$\begin{aligned} i_{q-1} &= k_q - (1 - \delta + \varpi)k_{q-1} \\ &= [y_{q-1} - n_{q-1} - d_q] + [\ell_{q-1} - \ell_q] + \left[ \frac{b_{q+1}}{1 + r_{q+1}} - b_q \right]. \end{aligned} \quad (7)$$

Equation (7) shows that investment can be funded through three channels: retained earnings ( $d_q$  is the dividend paid after  $y_{q-1}$  is realized), contained in the first set of brackets; cash reserves, contained in the second set of brackets; and new borrowing, contained in the third set of brackets.

Operating farms also face a liquidity constraint (Jermann and Quadrini, 2012):

$$n_q \leq \zeta \ell_q, \quad (8)$$

with  $\zeta \geq 1$ . Larger values of  $\zeta$  imply a more relaxed constraint, with farmers more able to fund operating expenses out of contemporaneous revenues. Because dairy farms provide a steady flow of income throughout the year, in an annual model  $\zeta$  is likely to exceed 1.

In addition to continued operation, a farm can reorganize or liquidate. If it chooses the second option, reorganization, some of its debt is written down.<sup>16</sup> The debt liability  $b_q$  is replaced by  $\hat{b}_q \leq b_q$  and the re-structured farm continues to operate. Finally, if the family decides to exit – the third option – the farm is liquidated and assets net of liquidation costs are handed over to the bank:

$$\begin{aligned} k_q &= 0, \\ a_q &= \max \{ (1 - \lambda)\tilde{a}_q - b_q, 0 \}. \end{aligned}$$

We assume that the information/liquidation costs of default are proportional to assets, with  $0 \leq \lambda \leq 1$ . Liquidation costs are not incurred when the family (head) retires at age  $Q$ .

The interest rate realized on debt issued at age  $q$ ,  $\hat{r}_{q+1} = \hat{r}_{q+1}(s_{q+1}, r_{q+1})$ , depends on the state vector  $s_{q+1}$  (specified below) and the contractual interest rate  $r_{q+1}$ . The function  $\hat{r}(\cdot)$  emerges from enforceability problems of the sort found in Kehoe and Levine (1993). If the farmer chooses to honor the contract,  $\hat{r}_{q+1} = r_{q+1}$ . If the farmer chooses

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<sup>16</sup>Most farms have the option of reorganizing under Chapter 12 of the bankruptcy code, a special provision designed for family farmers. Stam and Dixon (2004) review the bankruptcy options available to farmers.

to default,

$$\hat{r}_{q+1} = \frac{\min\{(1-\lambda)\tilde{a}_{q+1}, b_{q+1}\}}{b_{q+1}/(1+r_{q+1})} - 1 = (1+r_{q+1}) \frac{\min\{(1-\lambda)\tilde{a}_{q+1}, b_{q+1}\}}{b_{q+1}} - 1.$$

The return on restructured debt is  $\hat{r}_{q+1} = \left[ (1+r_{q+1}) \min\{\hat{b}_{q+1}, b_{q+1}\} / b_{q+1} \right] - 1$ . We assume that loans are supplied by a risk-neutral competitive banking sector, so that

$$E_q(\hat{r}_{q+1}(s_{q+1}, r_{q+1})) = r, \quad (9)$$

where  $r$  is the risk free rate. While we allow the family to roll over debt ( $b_{q+1}$  can be bigger than  $\tilde{a}_{q+1}$ ), Ponzi games are ruled out by requiring all debts to be resolved at retirement:

$$b_{Q+1} = k_{Q+1} = 0; \quad a_{Q+1} \geq 0.$$

To understand the decision to default or renegotiate, the family's problem needs to be expressed recursively. To simplify matters, we assume that the decision to work for wages is permanent, so that the Bellman equation for a worker is:

$$V_q^W(a_q) = \max_{0 \leq d_q \leq (1+r)a_q + w} u(d_q) + \beta V_{q+1}^W(a_{q+1}),$$

*s.t.* equation (3).

The Bellman equation for a family who has decided to fully repay its debt and continue farming is

$$V_q^F(e_q, \mu) = \max_{\{d_q \geq -c_0, b_{q+1} \geq 0, n_q \geq 0, k_q \geq 0\}} u(d_q) + \chi + \beta E_q(V_{q+1}(\tilde{a}_{q+1}, b_{q+1}, \mu)),$$

*s.t.* equations (4), (5), (6), (8), (9),

where  $V_{q+1}(\cdot)$  is the continuation value prior to the time- $q+1$  occupational choice:

$$V_{q+1}(\tilde{a}_{q+1}, b_{q+1}, \mu) = \max\{V_{q+1}^F(\tilde{a}_{q+1} - \min\{b_{q+1}, \hat{b}_{q+1}\}, \mu), V_{q+1}^W(\max\{(1-\lambda)\tilde{a}_{q+1} - b_{q+1}, 0\})\}.$$

We require that the renegotiated debt level  $\hat{b}_{q+1}$  is incentive-compatible:

$$\begin{aligned}\hat{b}_{q+1} &= \max\{b_{q+1}^*, (1 - \lambda)\tilde{a}_{q+1}\}, \\ V_{q+1}^F(\tilde{a}_{q+1} - b_{q+1}^*, \mu) &\equiv V_{q+1}^W(\max\{(1 - \lambda)\tilde{a}_{q+1} - b_{q+1}, 0\}),\end{aligned}$$

so that  $\hat{b}_{q+1} = \hat{b}_{q+1}(s_{q+1})$ , with  $s_{q+1} = \{\tilde{a}_{q+1}, b_{q+1}, \mu\}$ . The first line of the definition ensures that  $\hat{b}_{q+1}$  is incentive-compatible for lenders: the bank can always force the farm into liquidation, bounding  $\hat{b}$  from below at  $(1 - \lambda)\tilde{a}_{q+1}$ . However, if the family finds liquidation sufficiently unpleasant, the bank may be able to extract a payment,  $b_{q+1}^*$ , that is larger. The second line ensures that such a payment is incentive-compatible for farmers, i.e., farmers must be no worse off under this deal than they would be if they liquidated and switched to wage work.

A key feature of this renegotiation is limited liability. If the farm liquidates, the bank at most receives  $(1 - \lambda)\tilde{a}_{q+1}$ , and under renegotiation dividends are bounded below by  $-c_0$ . Our estimated value of  $c_0$  is small, implying that new equity is expensive and not an important source of funding. Coupled with the option to become a worker, limited liability will likely lead the continuation value function,  $V_{q+1}(\cdot)$ , to be convex over the regions of the state space where farming and working have similar valuations (Vereshchagina and Hopenhayn, 2009).

The debt contract also bounds repayment from above: the farm can always honor its contract and pay back  $b_{q+1}$ . Solving for  $\hat{b}_{q+1}$  allows us to express the finance/occupation indicator  $I_q^B \in \{\text{continue, restructure, liquidate}\}$  as the function  $I_q^B(s_q)$ . It immediately follows that

$$\begin{aligned}\frac{1 + \hat{r}_q(s_q, r_q)}{1 + r_q} &= 1\{I_q^B(s_q) = \text{continue}\} + \\ &1\{I_q^B(s_q) = \text{liquidate}\} \cdot \frac{\min\{(1 - \lambda)\tilde{a}, b_q\}}{b_q} + \\ &1\{I_q^B(s_q) = \text{restructure}\} \cdot \frac{\min\{\hat{b}_q(s_q), b_q\}}{b_q}.\end{aligned}$$

Inserting this result into equation (9), we can calculate the equilibrium contractual rate

as<sup>17</sup>

$$1 + r_q = [1 + r] / E_{q-1} \left( \frac{1 + \hat{r}_q(s_q, r_q)}{1 + r_q} \right). \quad (10)$$

## 4 Econometric Strategy

We estimate our model using a form of Simulated Minimum Distance (SMD). In brief, this involves comparing summary statistics from the DFBS to summary statistics calculated from model simulations. The parameter values that yield the “best match” between the DFBS and the model-generated summary statistics are our estimates.

Our estimation proceeds in two steps. Following a number of papers (e.g., French, 2005; De Nardi, French and Jones, 2010), we first calibrate or estimate some parameters outside of the model. In our case there are four parameters. We set the real rate of return  $r$  to 0.04, a standard value. We set the outside wage  $w$  to an annual value of \$25,000, or 2,000 hours at \$12.50 an hour. To a large extent, the choice of  $w$  is a normalization of the occupation utility parameter  $\chi$ , as the parameters affect occupational choice the same way. Using DFBS data, we set the capital depreciation rate  $\delta$  to 5.56% and the appreciation rate  $\varpi$  to 3.59%.<sup>18</sup>

In the second step, we estimate the parameter vector  $\Omega = (\beta, \nu, c_0, \chi, c_1, \theta, \alpha, \gamma, n_0, \lambda, \zeta)$  using the SMD procedure itself. To construct our estimation targets, we sort farms along two dimensions, age and size. There are two age groups: farms where the youngest operator was 39 or younger in 2001; and farms where the youngest operator was 40 or older. This splits the sample roughly in half. We measure size as the time-averaged herd size divided by the time-averaged number of operators. Here too, we split the sample in half: the dividing point is between 86 and 87 cows per operator. As Section 2 suggests, this measure corresponds closely to the fixed TFP component  $\mu_i$ . Then for each of these four age-size cells, for each of the years 2001 to 2011, we match:

1. The median value of capital per operator,  $k$ .
2. The median value of the output-to-capital ratio,  $y/k$ .

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<sup>17</sup>The previous equation shows that the ratio  $\frac{1 + \hat{r}_q(s_q, r_q)}{1 + r_q}$  is independent of the contractual rate  $r_q$ . Finding  $r_q$  thus requires us to calculate the expected repayment rates only once, rather than at each potential value of  $r_q$ , as would be the case if time- $t$  debt were denominated in time- $t$  terms. (In the latter case,  $b_{q+1}$  would be replaced with  $(1 + r_q)b_q$ .) This is a significant computational advantage.

<sup>18</sup>We find the depreciation (appreciation) rate by calculating the the ratio of depreciation expenditures (capital gains) to the market value of owned capital for each firm-year, and taking averages across the sample.

3. The median value of the variable input-to-capital ratio,  $n/k$ .
4. The median value of the gross investment-to-capital ratio.
5. The median value of the debt-to-asset ratio,  $b/\tilde{a}$
6. The median value of the cash-to-asset ratio,  $\ell/\tilde{a}$ .
7. The median value of the dividend growth rate,  $d_t/d_{t-1}$ .<sup>19</sup>

For each value of the parameter vector  $\Omega$ , we find the SMD criterion as follows. First, we use  $\alpha$  and  $\gamma$  to compute  $z_{it}$  for each farm-year observation in the DFBS, following equation (1). We then decompose  $z_{it}$  according to equation (2). This yields a set of fixed effects  $\{\mu_i\}_i$  and a set of aggregate shocks  $\{\Delta_t\}_t$  to be used in the model simulations, and allows us to estimate the means and standard deviations of  $\mu_i$ ,  $\Delta_t$ , and  $\varepsilon_{iq}$  for use in finding the model's decision rules. Using a bootstrap method, we take repeated draws from the joint distribution of  $s_{i0} = (\mu_i, a_{i0}, b_{i0}, q_{i0}, t_{i0})$ , where  $a_{i0}$ ,  $b_{i0}$  and  $q_{i0}$  denote the assets, debt and age of farm  $i$  when it is first observed in the DFBS, and  $t_{i0}$  is the year it is first observed. At the same time we draw  $\vartheta_i$ , the complete set of dates that farm  $i$  is observed in the DFBS.

Discretizing the asset, debt, equity and productivity grids, we use numerical methods to find the farms' decision rules. We then compute histories for a large number of artificial farms. Each simulated farm  $j$  is given a draw of  $s_{j0}$  and the shock histories  $\{\Delta_t, \varepsilon_{jt}\}_t$ . The residual shocks  $\{\varepsilon_{jt}\}_{jt}$  are produced with a random number generator, using the standard deviation of  $\varepsilon_{iq}$  described immediately above. The aggregate shocks we use are those observed in the DFBS. Combining these shocks with the decision rules allows us to compute that farm's history. We then construct summary statistics for the artificial data in the same way we compute them for the DFBS. Let  $g_{mt}$ ,  $m \in \{1, 2, \dots, M\}$ ,  $t \in \{1, 2, \dots, T\}$ , denote a summary statistic of type  $m$  in calendar year  $t$ , such as median capital for young, large farms in 2007. The model-predicted value of  $g_{mt}$  is  $g_{mt}^*(\Omega)$ . Our SMD criterion function is

$$\sum_{m=1}^M \sum_{t=1}^T \left( \frac{g_{mt}^*(\Omega)}{g_{mt}} - 1 \right)^2.$$

Because the model gives farmers the option to become workers, we also need to match some measure of occupational choice. We do not attempt to match observed attrition, because the DFBS does not report reasons for non-participation, and a number of farms

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<sup>19</sup>Because profitability levels, especially for large farms, are sensitive to total returns to scale  $1 - \alpha$ , we match dividend growth, rather than levels.

exit and re-enter the dataset. In fact, when data for a particular farm-year are missing in the DFBS, we treat them as missing in the simulations, using our draws of  $\vartheta_i$ . However, we also record the fraction of farms that exit in our simulations but not in the data. We use this fraction to calculate a penalty that is added to the SMD criterion.<sup>20</sup> Our estimate of the “true” parameter vector  $\Omega_0$  is the value of  $\Omega$  that minimizes this modified criterion.

Appendix ?? contains a detailed description of how we calculate standard errors.

## 5 Parameter Estimates and Identification

### 5.1 Parameter Estimates and Goodness of Fit

Table 5 displays the parameter estimates. We are still in the process of getting standard errors. While the estimated value of the discount factor  $\beta$ , 0.986, is fairly standard, the risk aversion coefficient  $\nu$  is only 0.24. This may reflect the ability of farmers to smooth consumption with their personal assets. The retirement parameters imply that farms value post-retirement consumption; in the period before retirement, farmers consume only 7.9% of their wealth, saving the rest.<sup>21</sup> The non-pecuniary benefit of farming,  $\chi$ , is expressed as a consumption increment to the non-farm wage  $w$ . With  $w$  equal to \$25,000, the estimates imply that the psychic benefit from farming is equivalent to the utility gained by increasing consumption from \$25,000 to \$73,900. Even when the outside wage is modest, the income streams from low productivity farms are so small that their operators would exit if they did not receive significant psychic benefits.

The returns to management and capital are both fairly small, implying that the returns to intermediate goods,  $1 - \alpha - \gamma$ , are in excess of 70 percent. Table 1 shows that variable inputs in fact equal about 77.5% of revenues. The liquidation loss,  $\lambda$ , is about 40 percent. This is at the upper range of the estimates found by Levin, Natalucci and Zakrajšek (2004), who note that many papers calibrate the loss to be between 10 and 20 percent. Given that a significant portion of farm assets are site-specific, higher loss rates are not

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<sup>20</sup>At the estimated parameter values for the baseline model, all farm-years observed in the DFBS are also observed in the simulations.

<sup>21</sup>This can be found by solving for the value of the optimal retirement assets  $a^r$ , in the penultimate period of the operator’s economically active life  $\max_{a^r \geq 0} \left\{ \frac{1}{1-\nu} (c_0 + x - a^r)^{1-\nu} + \beta \frac{1}{1-\nu} \theta \left( c_1 + \frac{a^r(1+r)}{\theta} \right)^{1-\nu} \right\}$  and finding  $\partial a^r(x)/\partial x|_{a^r=(a^r)^*}$ . A derivation based on a similar specification appears in De Nardi et al. (2010).

Parameter Description		
Discount factor	$\beta$	0.986
Risk aversion	$\nu$	0.240
Consumption utility shifter	$c_0$	4.19
Retirement utility shifter	$c_1$	10.84
Retirement utility intensity	$\theta$	10.84
Consumption value of farming	$\chi$	48.9
Returns to management	$\alpha$	0.171
Returns to capital	$\gamma$	0.122
Liquidation costs	$\lambda$	0.389
Degree of liquidity constraint	$\zeta$	2.30

Table 5: Parameter Estimates

implausible. The liquidity constraint parameter  $\zeta$  is estimated to be about 2.3, implying that farms need to hold liquid assets equal to about 5 months of expenditures.

Figures 4 and 5 compare the model’s predictions to the data targets. To distinguish the younger and older cohorts, the horizontal axis measures the average operator age of a cohort at a given calendar year. The first observation on each panel starts at age 29: this is the average age of the youngest operator in the junior cohort in 2001. Observations for age 30 corresponds to values for this cohort in 2002. When first observed in 2001, the senior cohort has an average age of 48. As before, thick lines denote large farms, and thin lines denote smaller farms. For the most part the model fits the data fairly well. The model understates the spending on variable inputs by large farms, and overstates the extent to which they reduce their debt. However, the model captures many of the differences between large and small farms, and much of the year-to-year variation.

## 5.2 Identification

The model’s parameters are identified from aggregate averages. Some linkages are straightforward. For example, the production coefficients  $\alpha$  and  $\gamma$  are identified by expenditure shares, and the extent to which farm size varies with productivity. The cash constraint  $\zeta$  is identified by the observed cash/asset ratio.

The identification of the preference parameters is less straightforward. Table 6 shows comparative statics for our model, which we find by repeatedly simulating the model while changing parameters in isolation. The numbers in the table are averages of the model-simulated data over the 11-year (pseudo-) sample period.

Row (1) shows data for the baseline model, associated with the parameters in Table 5.

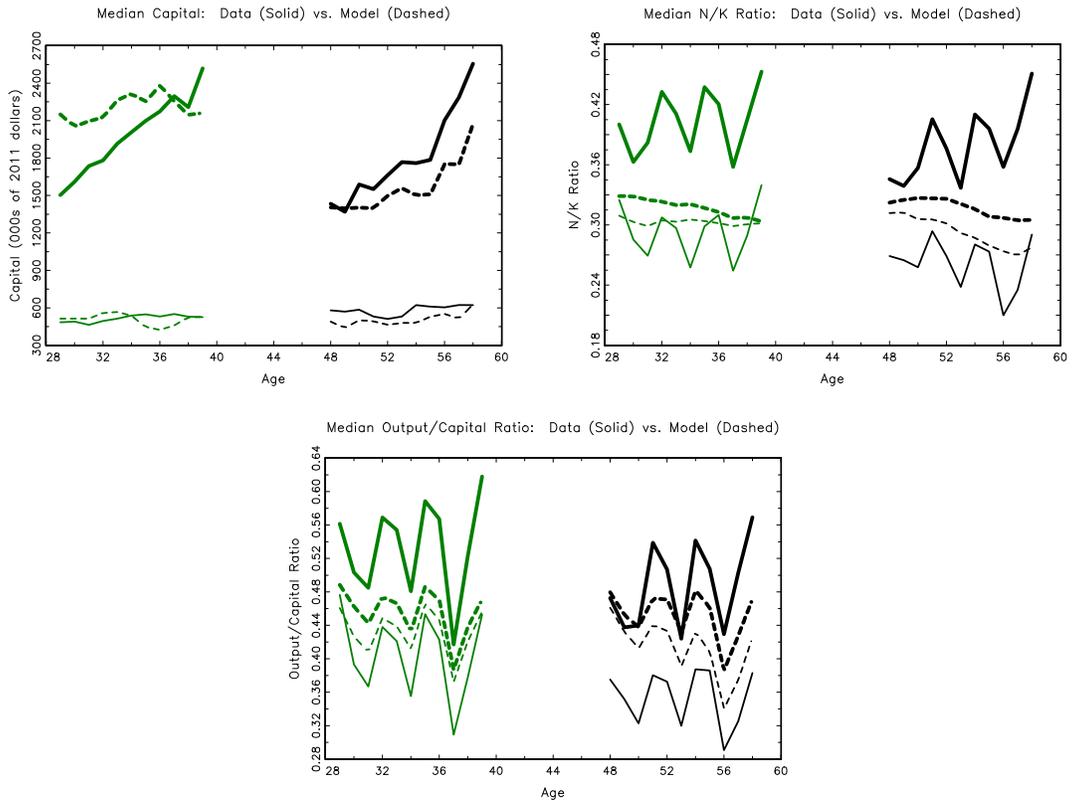


Figure 4: Model Fits: Production Measures

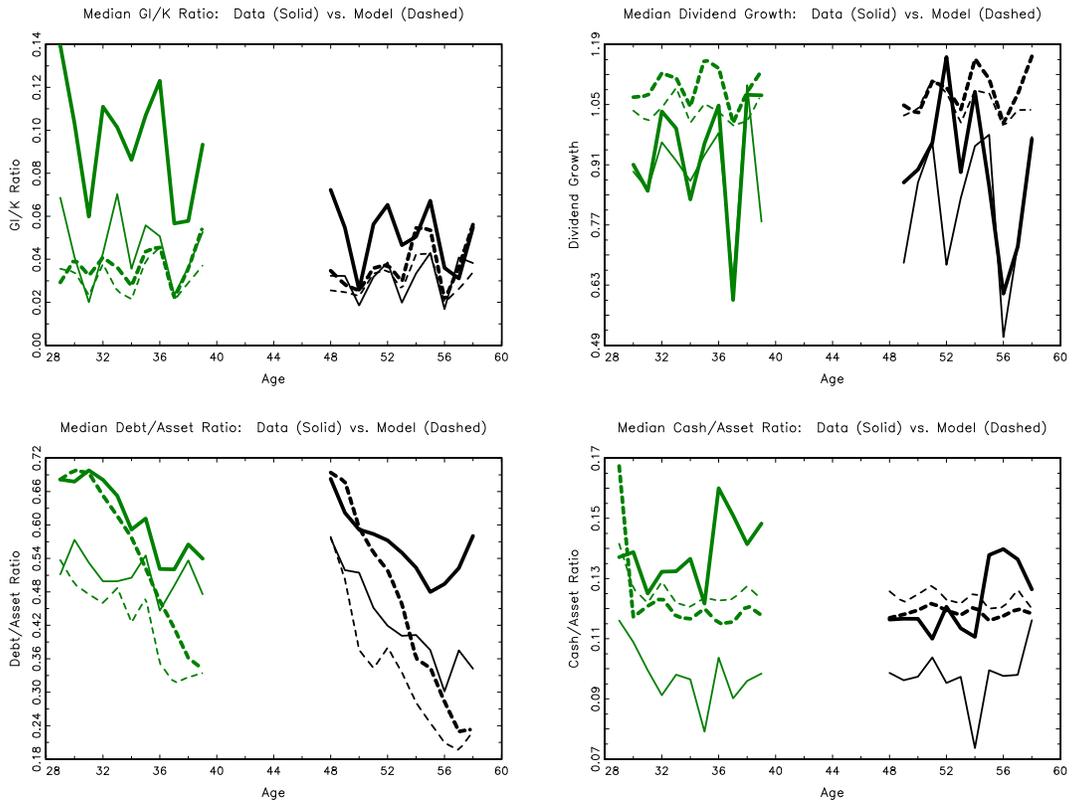


Figure 5: Model Fits: Financial Measures

Row (2) shows the averages that arise when the discount factor  $\beta$  is reduced to 0.975. Lowering  $\beta$  leads farms to hold less capital and invest less, as they place less weight on future returns. On the other hand, impatient farms purchase relatively more variable inputs: the  $N/K$  ratio rises from 0.305 to 0.319.<sup>22</sup> While farms can fund some of their variable inputs out of revenues, capital must be fully funded. Because lowering  $\beta$  raises the relative cost of providing funds through retained earnings (deferred dividends), it raises the cost of capital relative to intermediate goods, raising  $N/K$ . Both sets of changes help identify  $\beta$ . In addition,  $\beta$  is identified by the dividend growth rate rate, as larger values of  $\beta$  lead to faster growth.

Rows (3) and (4) show the effects of changing the risk coefficient  $\nu$ . When  $\nu = 0$ , farmers are risk-neutral. This leads them to hold less debt, as the borrowing rate  $r = 0.04$  exceeds the discount rate. Risk-neutrality also leads farmers to invest more aggressively in capital, as they are less concerned about its stochastic returns. In contrast, increasing  $\nu$  to 0.5 (row (4)) results in farmers holding more debt. The underlying simulations show that this debt is used to fund larger dividends in early years; because farmers have stronger dividend smoothing motives, they desire flatter dividend profiles. The utility shifter  $c_0$  is identified by similar mechanics.

The retirement parameters  $c_1$  and  $\theta$  are identified by life cycle variation not shown in Table 6. As  $\theta$  goes to zero, so that retirement utility vanishes, older farmers will have less incentive to invest in capital, and their capital holdings will fall relative to those of younger farmers.

The parameters  $\chi$  and  $\lambda$  are both identified by occupational choice, namely the estimation requirement that all farms observed in the DFBS in a given year also be operating and thus observed in the simulations. Row (5) shows the effect of setting the occupational utility term  $\chi$  to zero. Eliminating the psychic benefits of farming leads many farms to liquidate; the fraction of farms operating (and observed in the DFBS) drops from 55% to 49%. Not surprisingly, it is the smaller, low productivity farms that exit: the surviving farms in row (5) have more assets, debt and capital. Hamilton (2000) and Moskowitz and Vissing-Jørgensen (2002) find that many entrepreneurs earn below-market returns, suggesting that non-pecuniary benefits are large. (Also see Quadrini, 2009.) Figure 3 shows that many low-productivity farms have dividend flows smaller than the outside salary of \$25,000. This is consistent with a high value of  $\chi$ . Although our model includes limited liability and occupational choice, most low-productivity farms enter our sample with low levels of indebtedness and (relative to  $\mu_i$ ) high capital stocks (see Figures 2

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<sup>22</sup>In a frictionless static world, with full debt financing ( $r = 0.04$ ), the  $N/K$  ratio would be 0.344.

	Fraction Operating	Assets	Debt	Debt/ Assets	Cash/ Assets	Capital	$N/K$	Investment/ Capital
(1) Baseline Model	0.552	1,908	924	0.435	0.130	1,547	0.304	0.0381
(2) $\beta = 0.975$	0.552	1,852	987	0.467	0.130	1,480	0.317	0.0276
(3) $\nu = 0$	0.552	1,959	840	0.398	0.128	1,608	0.297	0.0459
(4) $\nu = 0.5$	0.552	1,845	975	0.461	0.138	1,472	0.317	0.0337
(5) $\chi = 0$	0.487	2,105	1,036	0.470	0.127	1,702	0.319	0.0386
(6) $\lambda = 0$	0.551	1,908	924	0.435	0.130	1,547	0.304	0.0382
(7) $\lambda = \chi = 0$	0.403	2,432	1,206	0.484	0.127	1,985	0.317	0.0388
(8) $c_0 = 2,000$	0.527	2,695	357	0.162	0.178	2,359	0.235	0.1194
(9) $\zeta = 1$	0.552	2,027	1,064	0.460	0.241	1,443	0.295	0.0359
(10) $\zeta = 4$	0.552	1,944	951	0.439	0.104	1,651	0.305	0.0375
(11) No Renegotiation	0.544	1,897	898	0.425	0.130	1,537	0.304	0.0381
(12) No Reneg., $\chi = 0$	0.429	2,279	1,093	0.452	0.124	1,838	0.332	0.0302

Table 6: Comparative Statics

and 3). In such circumstances the risk-taking incentives described by Vereshchagina and Hopenhayn (2009) are unlikely to apply. Vereshchagina and Hopenhayn (2009) also argue that patient firms are less likely to seek risky investment projects; our estimated discount rate is 1.4%.

Row (6) shows the effects of setting the liquidation cost  $\lambda$  to zero. Eliminating the liquidation cost *reduces* the number of operating farms, by allowing farmers to retain more of their wealth upon exiting.<sup>23</sup> While the effect of setting  $\lambda$  to zero in isolation is small, row (7) shows that in the absence of psychic benefits, eliminating liquidation costs encourages many more farms to exit. Liquidation costs thus provide another explanation of why entrepreneurs may persist in professions with low financial returns. We will discuss the effects of  $\lambda$  and other financial constraints in greater detail in the next section.

## 6 The Effects of Financial Constraints

Our model contains four important financial elements: liquidation costs, limits on new equity, the ability to renegotiate debt, and liquidity constraints. In this section, we consider the effect of each of these elements on assets, debt, capital and investment.

<sup>23</sup>Recall that we assume that liquidation costs are not imposed upon retiring farmers.

## 6.1 Liquidation Costs

Row (6) of Table 6 shows that eliminating liquidation costs ( $\lambda$ ) in isolation has very little effect. The non-pecuniary benefits of farming discourage almost all farms from exiting, and they encourage prudent financial behavior. If there are no non-pecuniary benefits ( $\chi = 0$ ), on the other hand, eliminating liquidation costs leads many more farms to exit. Rows (6) and (7) show that the fraction of operating farms drops from 49 to 40 percent. The remaining farms are significantly larger and more productive. Liquidation costs thus lead to financial inefficiency, by discouraging the reallocation of capital and labor to more productive uses.

Eliminating liquidation costs also encourages more lending, as lenders can appropriate larger amounts from farms in the event of default. Row (7) does indeed show higher levels of indebtedness. This increase, however, also reflects compositional changes.

## 6.2 Equity Injections

In addition to serving as a preference parameter,  $c_0$  limits the ability of farms to raise funds from equity injections. Row (8) shows the effects of increasing  $c_0$  to 2,000, allowing farmers to inject up to \$2 million of personal funds into their farms each year. Because farmers have a discount rate of 1.4 percent, as opposed to the risk-free rate of 4 percent, they greatly prefer internal funding over debt. Increasing  $c_0$  to 2,000 thus results in a dramatic decrease in debt, along with as significant increases in capital and assets. The reduced cost of funds also leads to a different input mix. Because capital becomes cheaper relative to intermediate goods, the  $N/K$  ratio falls from 30.4 to 23.5 percent.<sup>24</sup> Limits on new equity play an important role in our model.

## 6.3 Liquidity Constraints

Rows (9) and (10) illustrate the effects of the liquidity constraint given by equation (8). Row (9) of Table 6 shows what happens when we tighten this constraint by reducing  $\zeta$  to 1. While total assets and debt both modestly increase, the cash to asset ratio increases by 85 percent, from 12 to 17 percent. Rather than holding their assets in the form of capital, farms are obliged to hold it in the form of liquid assets used to purchase intermediate goods. This has important consequences for output, assets and capital. The average

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<sup>24</sup>Increasing  $c_0$  also decreases the incremental utility associated with farming, which is calculated as  $u(w + c_0 + 49) - u(w + c_0)$ , leading some farms to exit in later years.

capital stock falls by 6.7 percent, from 1,547 to 1,443, as more funds are diverted to cash. Purchases of intermediate goods also fall. Output falls by 7.8 percent.

Loosening the liquidity constraint ( $\zeta = 4$ ) allows farms to hold a larger fraction of their assets in productive capital, raising the assets' overall return. Farms respond by borrowing more and purchasing more capital. The average debt level increases by about 3 percent, while the capital stock increases by about 7 percent. Total assets increase by 2 percent, leading to higher debt to asset ratios. The intermediate goods to capital ratio remains almost the same, suggesting that the purchase of intermediate goods also increase substantially. Output is consequently 5.7 per cent higher than in the baseline case. Relaxing the liquidity constraint has significant real effects.

## 6.4 Renegotiation of Debt Contracts

Finally we explore the role of contract renegotiation in our model. Row (11) of Table 6 shows the effects of eliminating renegotiation and requiring farms with negative net worth to liquidate. The main effect of this change is that any farms that enter the DFBS with negative net worth are forced out immediately in our simulations. The fraction of farms observed drops by about 1.5 percent. There is virtually no exit among the other farms, however, because of their intrinsic preference for farming. Interestingly, assets and capital *decline* slightly, as the exiting farms were *not* from the lower tail of the productivity distribution. Renegotiation can therefore play an important role in keeping productive farms alive.

Row (12) illustrates the combined effects of eliminating renegotiation and setting  $\chi = 0$ . The number of operating farms falls significantly, by about 22 percent. The exiting farms definitely come from the lower tail of the productivity distribution, as the surviving farms on average have about 19 percent more capital and assets. Insolvent low-productivity farms are far more willing to roll over their debt when farming provides psychic benefits.

## 6.5 Cross-sectional Evidence

While the comparative statics presented above give a good picture of the behavior of the average farm, it is also interesting to also study the cross sectional variation. Another way to assess the importance of the model's financial mechanisms to repeat the regressions in Tables 3 and 4 on simulated data. Such an exercise also provides useful out-of-sample validation. The results are presented in Tables 7 and 8 respectively.

	Regression Coefficients: Dependent Variable $(\omega_{it} - 1)^2$			
	Coeff.	Std. Err	Coeff.	Std. Err
$z_{it}$	-0.056*	0.003	-0.074*	0.003
Total Assets	-0.005*	0.000		
Net Worth			-0.011*	0.000
Individual Effects	Yes		Yes	
Time Dummies	Yes		Yes	

Table 7: Input Distortions with Simulated Data

	Net Investment/ Owned Capital		Gross Investment/ Owned Capital	
	(1)	(2)	(3)	(4)
TFP ( $z_{it}$ )		-6.949*		-6.949*
		0.043		0.043
TFP $\mu_i$	-0.030*		-0.030*	
	0.001		0.001	
Cash Flow/Capital	0.459*	2.997*	0.459*	2.997*
	0.004	0.016	0.004	0.016
Operator Age	0.000	0.005*	0.000	0.005*
	0.000	0.000	0.000	0.000
Year Effects	Yes	Yes	Yes	Yes
Fixed Effects	No	Yes	No	Yes

Table 8: Investment-Cash Flow Regressions with Simulated Data

Table 7 shows that the model-generated data displays behavior very similar to the actual data. Firms with higher assets or net worth still come closer to reaching their optimal input mix, through better access to funding. Table 8 shows that our model also generates a positive relation between cash flow and investment, even after controlling for productivity. Larger cash flow (defined as the difference between revenue and input expenditures) implies more assets, which can then be used for leverage or to finance investment expenditure directly.

## 6.6 Overview

To sum up: our estimates and policy experiments suggest that financial factors play an important role in farm outcomes. Our model is rich enough to distinguish between many types of constraints and quantify their importance. The liquidity constraint on variable inputs seems to be the constraint with the maximum impact, in the sense that relaxing it can increase assets, capital and output of farms substantially. Similar borrowing constraints have been shown to play an important role in financial crises in Latin America and East Asia (see for example Pratap and Urrutia 2012, Mendoza 2010). There is also evidence that the ability to renegotiate debt allows productive farms to remain operational.

Although, the costs associated with liquidation seem important in terms of the social waste they engender (40 percent of assets), removing them does not seem to alter farm outcomes substantially. This is because of the non-pecuniary benefits of farming. Because low productivity farms generate very small income streams, and enter our sample with relatively low leverage, our model can rationalize their operation only by assigning a large psychic benefit to farming. The intrinsic utility of farming leads farms to avoid liquidation, regardless of its cost. In the absence of this benefit, however, liquidation costs have significant effects, as they discourage low-productivity farms from exiting. In our model, this reallocation effect of liquidation costs appears at least as significant as any borrowing restrictions.

## 7 Conclusion

Using a rich panel of New York State dairy farms, we estimate a structural model of farm investment, liquidity and production decisions. Farms face uninsured idiosyncratic and aggregate risks, as well as cash-flow constraints on variable expenditures. They enter

into debt contracts that account for liquidation costs and allow for renegotiation. Farmers choose their occupation, and can exit farming through retirement as well as liquidation. The combination of occupational choice and bankruptcy protection introduces the possibility of risk-seeking behavior (Vereshchagina and Hopenhayn, 2009). Using a simulated minimum distance estimator, we find that our model can account for several aspects of the time series and cross sectional variation in the data.

Our model allows us to quantify the importance of each type of financial constraint. We find that the short-term borrowing constraint on the purchase of variable inputs exerts a strong influence on investment, asset accumulation and liquidity management decisions of farms. The renegotiability of the debt contract allows productive farms to remain operational when they experience transitory setbacks. Liquidation costs are large, suggesting that their removal could be socially beneficial. As in the data, our model also predicts that financial health is important for farm investment and its ability to use inputs optimally.

We find that high-productivity farms are further below their optimal scale than low-productivity farms, suggesting a significant misallocation of resources. On the other hand, our estimates indicate that the non-pecuniary benefits of farming are an important force in keeping many farms operational. Removing them (or equivalently, improving outside opportunities for farmers) would lead to a significant exit of farms in the lower tail of the productivity distribution. Because they discourage exit, the psychic benefits also play an important role in the structure of the debt contract. In the absence of psychic benefits, liquidation costs also discourage exit, suggesting that they too could hinder the reallocation of capital.

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