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An Estimated Structural Model of Entrepreneurial Behavior†

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Using a rich panel of owner-operated New York dairy farms, we provide new evidence on entrepreneurial behavior. We formulate a dynamic model of farms facing uninsured risks and financial constraints. Farmers derive nonpecuniary benefits from operating their businesses. We estimate the model via simulated minimum distance, matching both production and financial data. We find that financial factors and nonpecuniary benefits are of first-order importance. Collateral constraints and liquidity restrictions inhibit borrowing and the accumulation of capital, especially among high-productivity firms seeking to expand. The nonpecuniary benefits to farming are large and keep small, low-productivity farms in business. Although farmers are risk averse, eliminating uninsured production risk has only modest effects on capital and output. (*JEL* C51, D24, G32, Q12, Q14)

Four out of five US businesses are owner-operated. What mechanisms explain their behavior? While many researchers have focused on the importance of financial constraints, others have highlighted nonpecuniary benefits of entrepreneurship, such as flexible hours and being one's own boss. Another strand of the literature emphasizes heterogeneity among firms, both in productivity and in risk-taking. Assessing the relative importance of these mechanisms is a priority for policy design. For example, a common rationale for subsidizing small businesses is to ease financial constraints that limit their ability to pursue productive investments. The value of such subsidies is less apparent if entrepreneurs are motivated mainly by nonpecuniary considerations.

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In this paper we evaluate the importance of all these mechanisms by formulating and estimating a rich model of entrepreneurial behavior. Risk-averse entrepreneurs make borrowing, investment, production, dividend, and liquidation decisions. They face uninsured production risk, along with collateral and liquidity constraints, but also receive nonpecuniary benefits from operating their business. Older entrepreneurs retire, and entrepreneurs of any age can liquidate their business and exit to wage work, albeit with liquidation costs. Limited liability and the outside option of wage work create incentives for risk taking. To our knowledge, this is the first model to combine all of these features and evaluate them empirically. As we will discuss in detail, this joint estimation is crucial if we want to estimate each of these features correctly.

We estimate the model using a detailed panel of family-owned-and-operated dairy farms in New York state. Using a simulated minimum distance estimator we match both production and financial data. Counterfactual experiments allow us to quantify the effects of relaxing financial constraints, eliminating nonpecuniary benefits, and reducing or eliminating uninsured production risk.

Our main finding is that the effects of financial constraints and nonpecuniary benefits are of first order, but those of risk are not. Financial constraints exert a strong influence on the intensive margin of operation, i.e., on investment and output. Collateral constraints hinder capital accumulation, especially among high-productivity firms seeking to expand. Liquidity constraints force firms to hold cash and divert resources from investment, with similar but smaller effects. Nonpecuniary benefits affect the extensive margin, i.e., the decision to continue operations. The least productive farms in our data have very low financial returns and it is difficult to justify their existence without nonpecuniary benefits. Liquidation costs also work at the same margin, by impeding the exit of unprofitable firms. The joint effect of these two mechanisms is much larger than the sum of their individual effects.

In contrast, production risk appears to play a minor role. The parameter estimates reveal a high degree of risk aversion. Along with the nonpecuniary benefits to farming, this mutes the appetite for risk-taking, despite limited liability and the ability to exit to wage work, which reduce downside risk. Eliminating uncertainty in production leads to only a modest expansion in operations, especially compared to the effects of relaxing financial constraints. As we discuss in detail below, an important caveat is that our model significantly underpredicts dividend volatility. Our estimates of risk aversion are therefore likely to be inflated, and the modest effects of eliminating production risk that we find are likely to be conservative.

These features are reflected in the response to recent changes in US dairy policy. The 2014 Farm Bill replaced the existing system of milk price supports, which were too low to be binding, with margin (milk prices net of unit feed costs) supports (Schnepf 2014). We estimate what the impact of these margin supports would have been in our 2001–2011 sample period and we find that this insurance would have had only a minor effect on farm operations. The premium charged for these supports, however, would have had large, negative consequences.

Related Literature.—A major stream of the literature emphasizes the importance of financial constraints in shaping the entry, survival, and growth of firms. Evans and Jovanovic (1989) and Blanchflower and Oswald (1998) find that wealthier individuals are more likely to become entrepreneurs.[1] Financial constraints also limit the operations of ongoing firms, as suggested by evidence that entrepreneurs have higher savings rates and invest much of their wealth in their own businesses (Quadrini 2000, 2009; Cagetti and De Nardi 2006; Herranz, Krasa, and Villamil 2015). A similar pattern is observed for publicly traded firms. Fazzari et al. (1988) and a large reduced-form literature that followed found evidence that small firms tended to respond strongly to increases in internal funds.[2] Structural approaches such as those of Pratap and Rendón (2003) and Hennessy and Whited (2007) yield similar conclusions.

While this literature would support financial policies targeted toward smaller firms, evidence on the efficacy of such policies is mixed. Kaboski and Townsend (2011) finds that the Thai Million Baht Village microcredit intervention increased borrowing and consumption almost one for one, with no increase in investment. Bauchet, Morduch, and Ravi (2015) finds virtually no impact of an asset grant program to the poor in India. De Mel, McKenzie, and Woodruff (2014) shows that capital injections lead to temporarily higher profits but no sustained growth in Sri Lanka. Asset grant programs seem to be more effective for already profitable (or larger) businesses (Fafchamps et al. 2014) or for the right tail of the wealth distribution (Bleakley and Ferrie 2016).

Buera, Kaboski, and Shin (2015) argues that introducing heterogeneous entrepreneurial productivity (as in the classic papers of Lucas 1978, Jovanovic 1982, and Hopenhayn 1992) into models with financial constraints can provide some context for these findings. The aggregate effect of relaxing borrowing constraints depends on how the constraints vary across the productivity distribution. Tighter borrowing constraints could force less-productive firms to exit and, by changing the mix of firms to high-productivity ones, actually increase output.

On the other hand, the incidence of financial constraints can be hard to explain. Hurst and Pugsley (2017) documents the existence of a large number of small, old firms, i.e., firms that never grow and never exit. Compared to similar young firms, they respond less to business cycle shocks (Fort et al. 2013) and create fewer jobs (Haltiwanger, Jarmin, and Miranda 2013). It is hard to believe that these firms are liquidity-constrained, given evidence that surviving firms can eventually accumulate their way out of financial constraints (Midrigan and Xu 2014).

Moreover, there is substantial evidence that entrepreneurs earn less than comparable workers (Hamilton 2000), that undiversified entrepreneurial investments earn no more than publicly traded equity (Moskowitz and Vissing-Jørgensen 2002), and that the risk-adjusted returns to venture capital are small (Hall and Woodward 2010).[3] Training programs designed to enhance entrepreneurial productivity have had little success. Fairlie, Karlan, and Zinman (2015) finds that the GATE (Growing America through Entrepreneurship) program, the largest randomized experiment on

[1] Hurst and Lusardi (2004) finds that the positive relationship between wealth and firm creation is restricted to the top 5 percent of the wealth distribution.

[2] Using a sample of farms in Kansas, Bierlen and Featherstone (1998) finds evidence of financial constraints for highly indebted farms and those with young operators. See Bushman, Smith, and Zhang (2011) for a review of the large and contentious literature around the investment-cash flow relationship.

[3] Kartashova (2014) argues that the "private equity puzzle" does not exist outside the 1990s, a period of unusually high public equity returns. Sarada (2016) shows that the earnings differential may be in part due to mismeasurement.

entrepreneurial training in the United States, had no effect on business scale, household income, or work satisfaction. McKenzie and Woodruff (2014) surveys evaluations of business training programs all over the world and finds sparse evidence of long-term benefits. The occupational choice of many entrepreneurs thus seems puzzling.

A potential explanation for these results is the existence of nonpecuniary benefits of entrepreneurship. Hurst and Pugsley (2011, p.73) documents that nonpecuniary benefits "play a first-order role in the business formation decision." Survey evidence shows that in general, entrepreneurs report greater job satisfaction than wage workers, as documented by Blanchflower (2000) for the OECD, Andersson (2008) for Sweden, and Benz and Frey (2008) for Germany, United Kingdom, and Switzerland. Entrepreneurs receiving nonpecuniary rewards may not be seeking high returns, and indeed may not even be capable of generating them. As Hamilton, Papageorge, and Pande (2019, p. 643) reports, "the personality traits that make entrepreneurship profitable are not always the same traits driving people to open a business."

The income differentials between entrepreneurs and wage workers may also reflect differences in risk-taking behavior. A third branch of the literature considers this issue. Kihlstrom and Laffont (1979) constructs a model where risk-loving individuals select into entrepreneurship, while Vereshchagina and Hopenhayn (2009) shows that limited liability can encourage risk-taking behavior among entrepreneurs even without a risk premium.

Our Results in Context.—This paper makes two key contributions. First, as mentioned above, to the best of our knowledge we are the first to formulate and estimate a model of entrepreneurial behavior that jointly accounts for financial constraints, nonpecuniary benefits, and risk-taking, and to quantify the nonpecuniary benefits of entrepreneurship. A joint treatment is essential because, as we show in Section VD, none of the mechanisms can be estimated accurately in isolation. Most notably, our estimation procedure returns significant nonpecuniary benefits as a way to explain the continuing operation of very small, low-productivity farms. In the absence of nonpecuniary benefits, our procedure underestimates the returns to scale, (counterfactually) increasing the profitability of the low-productivity farms so that they choose to remain in operation. But lowering the returns to scale also reduces the desire of high-productivity farms to invest, and leads to the erroneous conclusion that borrowing constraints are relatively unimportant, and that growth is limited mostly by productivity.

Our results indicate that the effectiveness of size-dependent policies, whether aimed at relaxing borrowing constraints or at improving productivity, is attenuated by nonpecuniary benefits. The presence of nonpecuniary benefits means that firm size is not only an inadequate proxy for either productivity or financial constraints, but that care must be taken when estimating productivity and financial constraints themselves.

Our second contribution concerns the identification of the dynamic mechanisms of the model. We have comprehensive panel data on real and financial variables for one industry in one region, which facilitates identification, while minimizing the problems associated with unobserved heterogeneity. For example, we can estimate financial constraints directly from investment and debt dynamics, rather than from the cross-sectional relationships used in most other entrepreneurship studies.[4] In particular, using the parameters of the model, we calculate revenue productivity shocks for each firm, which we can then decompose into a permanent farm-specific component, an aggregate shock tied to the price of milk, and an idiosyncratic transitory component. High values of the aggregate shock are associated with higher aggregate investment. Since aggregate productivity appears serially uncorrelated, this association suggests high milk prices promote investment by increasing cash flow, rather than by signaling higher future productivity. Volatile revenue shocks also enable us to analyze the effects of risk, and farm exit decisions identify nonpecuniary benefits. Such identification is not possible in the cross-sectional datasets typically used in the literature.[5]

The rest of the paper is organized as follows. In Section I we describe our data and perform some diagnostic reduced-form exercises. Section II sets out the model and Section III describes our estimation procedure. Section IV presents our parameter estimates, assesses the model's fit, and discusses parameter identification. Section V elaborates on the mechanisms of the model, considering nonpecuniary benefits, financial constraints, risk aversion, and their interactions. Section VI evaluates the effects of the 2014 Farm Bill. Section VII contains sensitivity analyses. We conclude in Section VIII.

I. Data and Descriptive Analysis

A. *The Dairy Farm Business Summary* (*DFBS*)

The Dairy Farm Business Summary (DFBS) is an annual survey of New York dairy farms conducted by the Dyson School of Applied Economics and Management at Cornell University.[6] 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 both market and book value. The data are extensively reviewed by the DFBS staff, who also construct income statements, balance sheets, cash flow statements, and a variety of productivity and financial measures (Dyson School 2006, 2015b; Karszes, Knobluch, and Dymond 2013). Participants can use these measures to compare their management practices with those of their peers. These diagnostics are an important benefit of participation in the survey, which is voluntary (Dyson School 2015a). We therefore expect the data to be of high quality, a supposition that is confirmed by internal data consistency checks.

[4] See, for example, Cagetti and De Nardi (2006) and Quadrini (2000), which use the Survey of Consumer Finances, and Herranz, Krasa, and Villamil (2015), which uses the Survey of Small Business Finances.

[5] While the structural corporate finance literature (see Pratap and Rendón 2003, Hennessy and Whited 2007) uses panel data on publicly traded firms, these are not comparable to our data, where the firms are all family-owned and operated. Caggese (2007, 2012, 2019), which use a panel of balance sheet data on unlisted Italian companies, are exceptions. The focus of these papers is also almost exclusively on the effects of financial frictions on risk-neutral firms, while we are more interested in the relationship between risk, financial constraints, and the nonpecuniary benefits of entrepreneurship. Likewise the focus of the development literature, where structural models of entrepreneurship have been estimated with firm-level panel data, often from Townsend's Thai surveys (e.g., Karaivanov and Townsend 2014), has been on financial factors and risk, to the exclusion of nonpecuniary considerations.

[6] The DFBS data are confidential and proprietary. Inquiries may be sent to dfbs@cornell.edu.

Our dataset is an extract of the DFBS covering the calendar years 2001–2011 (Dyson School 2001–2011). This is an unbalanced panel of 541 distinct farms, with approximately 200 farms surveyed each year. Since our model is explicitly dynamic, we eliminate farms with observations for only one year. We also remove farms for which there is no information on the age of the owners/operators,[7] as we expect retirement considerations to influence both production and finance decisions on family-operated farms. These filters leave us with a final sample of 363 farms and 2,222 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 all New York dairy farms.

The DFBS is not a representative sample: the average farm in the DFBS data is considerably larger than the population average for New York State.[8] Because we explicitly control for a number of size-related variables in our model, the key issue is whether the parameters for preferences, nonpecuniary benefits, and financial constraints are size-invariant. An identifying assumption (and concession to sample size) of our estimation procedure is that they are. A plausible alternative hypothesis is that smaller, less-productive farms face more stringent financial constraints, all else equal. If so, our finding that financial constraints are important is conservative.

Combining the distribution of herd sizes in the DFBS with the distribution for New York State in the Census of Agriculture (United States Department of Agriculture, various years), we can construct crude herd size weights for the DFBS.[9] We use these weights in our comparative statics exercises, so that our results are, to some extent, representative for New York. We do not use the weights to estimate the model because, under our assumption that the structural parameters are size-invariant, the unweighted estimator is more efficient (Wooldridge 1999). We discuss weighted parameter estimates in the online Appendix.

B. *Summary Statistics*

Table 1 provides summary statistics for our sample. The variable definitions and construction are described in greater detail in the online Appendix. The median farm is operated by two individuals and more than 80 percent of 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 eight 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.

[7] Since all the farms in our sample are operated by their owners, we will use these terms interchangeably.

[8] In 2011, average revenue in our sample was $2,887,000, 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 505. However, the sample is very similar to state averages in terms of demographics: 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).

[9] We are grateful to an anonymous referee for this suggestion.

Table 1—Summary Statistics from the DFBS

Variable	Mean	Median	Standard deviation	Maximum	Minimum
Number of operators	1.79	2	0.87	6	1
Operator 1 age	51.36	51	10.83	87	16
Youngest operator age	43.12	43	10.69	74	12
Herd size (cows)	374	186	434	3,656	20
Total capital	3,329	1,932	3,622	28,247	212
Machinery	753	483	760	5,335	13
Real estate	1,715	966	1,949	15,161	0
Livestock	861	432	1,030	9,027	39
Owned capital	2,693	1,594	2,934	26,478	83
Machinery	562	360	576	3,776	3
Real estate	1,296	756	1,509	14,196	0
Livestock	835	424	980	9,027	39
Owned/total capital	0.84	0.87	0.12	1.00	0.26
Revenues	1,778	822	2,202	16,929	47
Total expenses	1,510	675	1,900	15,685	43
Variable inputs	1,389	613	1,769	15,203	36
Leasing and interest	121	58	154	1,255	0
Total assets	3,242	1,869	3,579	31,414	103
Cash	548	257	721	5,689	6
Total liabilities	1,508	786	1,709	11,423	0
Net worth	1,733	874	2,314	21,278	−734
Dividends	72	46	176	4,058	−2,327

Note: Financial variables are expressed in thousands of 2011 dollars.

Table 1 shows that these are substantial enterprises: the yearly revenues of the average farm are in the neighborhood of 1.8 million in 2011 dollars. The distribution of revenues is heavily skewed to the right, with median farm revenues equal to less than one-half of the mean. Revenues have risen quickly over time, with average revenues in 2011 of $2.89 million. For comparison, census data from the Statistics of US Business (SUSB) show that in 2012 average revenues among proprietorships, partnerships, or S corporations were $2.76 million. In fact, along much of its range the revenue distribution in the DFBS resembles that in the SUSB. A more detailed comparison of this distribution can be found in the online Appendix.

A large part of farm expenses are accounted for by variable inputs: intermediate goods and hired labor. Of these, labor expenses are relatively minor, comprising about 14 percent of all expenditures on variable inputs.[10] The remainder consists of intermediate goods and services such as feed, fertilizer, seed, pest control, repairs, utilities, and insurance. We also report the amounts spent on capital leases and interest, which are less than 10 percent of total expenditures for the median farm.

Capital stock consists of machinery, real estate (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 13 percent of its capital, mostly real estate and machinery (see the online Appendix). Livestock is almost always owned. Capital is the predominant asset, making up more than 85 percent of farm assets, while liquid assets (what we call cash) account for the rest.

[10] Hired labor costs are 41 percent of value added on average; 53 of the 363 farms never use hired labor at all.

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. The average farm has a net worth of \$1.7 million. Only 28 (or 1.3 percent) of all farm-years report negative net worth.

Farms generate relatively little disposable income. The average dividend remitted to the farm's owners is \$72,000, while the median is \$46,000. Because the farms' owners also supply most of the labor, these returns are quite modest.

Much more of the farm's operating income is invested. The DFBS reports net investment and depreciation for each type of capital, allowing us to construct a measure of gross investment. Following the literature, we 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) uses data from the Longitudinal Research Database (LRD) to show that plant-level investment often occurs in large increments, suggesting a prominent role for fixed investment costs. For reference, Table 2 reproduces the statistics for gross investment rates shown in their Table 1. Investment spikes are less frequent in the DFBS than in the LRD. The average investment rate is also a bit lower. Although the inaction rate is marginally higher in our sample, the comparison as a whole suggests that fixed investment costs are less important in the DFBS, and in the interest of tractability we omit them from our structural model.

Farm technologies can be divided into two categories: stanchion barns and milking parlors, the latter considered the newer and larger-scale technology. About 60 percent of the farms in our sample are parlor operations. Table 3 displays summary statistics for each technology group. Stanchions are smaller than parlors, both in herd size and capital stock per operator. They invest less, have lower debt-to-asset ratios, and hold less cash. Interestingly, they also have lower output-to-capital ratios, and use fewer intermediate goods per unit of capital. These differences are consistent with both heterogeneous production functions and with heterogeneous exposure to financial constraints that distort the mix of inputs. Our model and estimation will allow for both possibilities.

C. *Productivity*

Our Productivity Measure.—We assume that farms utilize a Cobb-Douglas production function

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

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_i.[11] The variable K_{it} denotes the capital stock; N_{it} represents expenditure on all variable inputs, including hired labor and intermediate goods; and z_{it} is a stochastic revenue shifter reflecting both idiosyncratic and systemic factors.[12] With the exception of operator labor, all

[11] More than two-thirds of the farms display no change in family size.

[12] The assumption of decreasing returns to scale in nonmanagement inputs is consistent with the literature. Tauer and Mishra (2006) finds slightly decreasing returns in the DFBS. They argue that while many studies find

TABLE 2—INVESTMENT RATES

	DFBS	LRD
Average investment rate	0.087	0.122
Inaction rate ($<$ abs(0.01))	0.093	0.081
Fraction of observations < 0	0.086	0.104
Positive spike rate (> 0.2)	0.077	0.186
Negative spike rate (< -0.2)	0.003	0.018
Serial correlation	0.106	0.058

Notes: Column *DFBS* summarizes gross investment to owned capital ratios in the Dairy Farm Business Survey. Column *LRD*, taken from Cooper and Haltiwanger (2006, Table 1), shows corresponding statistics from the Longitudinal Research Database.

TABLE 3—MEDIANS BY TECHNOLOGY

	Stanchion	Parlor
Number of farms	146	217
Number of operators	1	2
Total capital	597	1,710
Herd size (cows)	52	181
Output/capital	0.37	0.51
Intermediate goods/capital	0.27	0.40
Investment/capital	0.04	0.07
Debt/assets	0.43	0.49
Cash/assets	0.11	0.16

Note: Capital and herd size measured on a per-operator basis.

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

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

In this formulation, returns to scale are $1 - \alpha < 1$, where α measures an operator's "span of control" (Lucas 1978).

Following Alvarez, Corral, and Tauer (2012) and based on the descriptive statistics in Table 3, we allow for two production technologies. Using the structural estimates described below, we find that for stanchion operations $\hat{\alpha} = 0.126$ and $\hat{\gamma} = 0.177$ and for milking parlors $\hat{\alpha} = 0.113$ and $\hat{\gamma} = 0.121$. In other words, parlor operators have higher returns to scale but lower returns to capital than stanchions. These estimates allow us to calculate total revenue productivity as

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

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" (Tauer and Mishra 2006, p. 4940) In our sample, farms with 2 operators use about 1.8 times the capital to produce about 2.05 times the output of farms with 1 operator, suggesting that they are also more efficient.

We assume that the resulting productivity measure can be decomposed into the individual fixed effect μ_i, a time-specific component, common to all farms, Δ_t, and the idiosyncratic i.i.d. component ε_{it}:

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

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 has a mean of 0.823 but ranges from 0.036 to 1.204 with a standard deviation of 0.155, implying significant time-invariant differences in productivity across farms. The time effect Δ_t is constructed to be zero mean. This series is effectively uncorrelated and has a standard deviation of 0.059. The idiosyncratic residual ε_{it} can also be treated as uncorrelated, with a standard deviation of 0.070.

As a measure of revenue productivity, z_{it} captures variation in prices as well as productivity. Because dairy farmers are by and large price takers, however, price variation should affect only the aggregate component Δ_t. Figure 1 plots Δ_t against real milk prices in New York State (New York State Department of Agriculture and Markets 2012). The aggregate shock follows milk prices very closely; the correlation is over 90 percent, which gives us confidence in our interpretation.[13] We thus feel comfortable assuming that the transitory shock ε_{it} and especially the fixed effect μ_i measure physical productivity.[14]

In Figure 1 we also 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 productivity measure. Cash flow varies quite significantly, indicating that farms face significant financial risk.

Productivity and Farm Characteristics.—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, μ_i. We divide the sample into high- and low-productivity farms, splitting around the median value of μ_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. Ninety-eight percent of the stanchions are low-productivity farms, and almost 80 percent of the low-productivity farms are stanchions. Eighty-two percent of the parlor operations are high-productivity farms, and almost all (98 percent) of the high-productivity farms are parlors.

[13] The series in Figure 1 is consistent with the belief that milk prices follow a three-year cycle. Nicholson and Stephenson (2014) finds 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 (p. 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[.]"

[14] Our assumption of perfect competition rules out the firm-level differences in market power or product demand emphasized by Foster, Haltiwanger, and Syverson (2008). Hsieh and Klenow (2009, Appendix I) shows that their framework for measuring productivity, with constant returns to scale in production and monopolistic competition ("diminishing returns in utility") is isomorphic to our framework, with decreasing returns to scale in production and perfect competition.

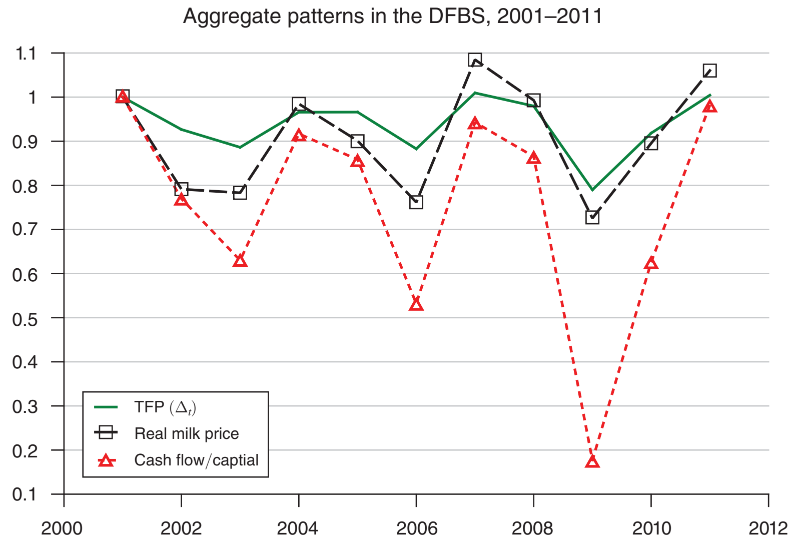

Figure 1. Aggregate Productivity, Real Milk Prices, and Cash Flow

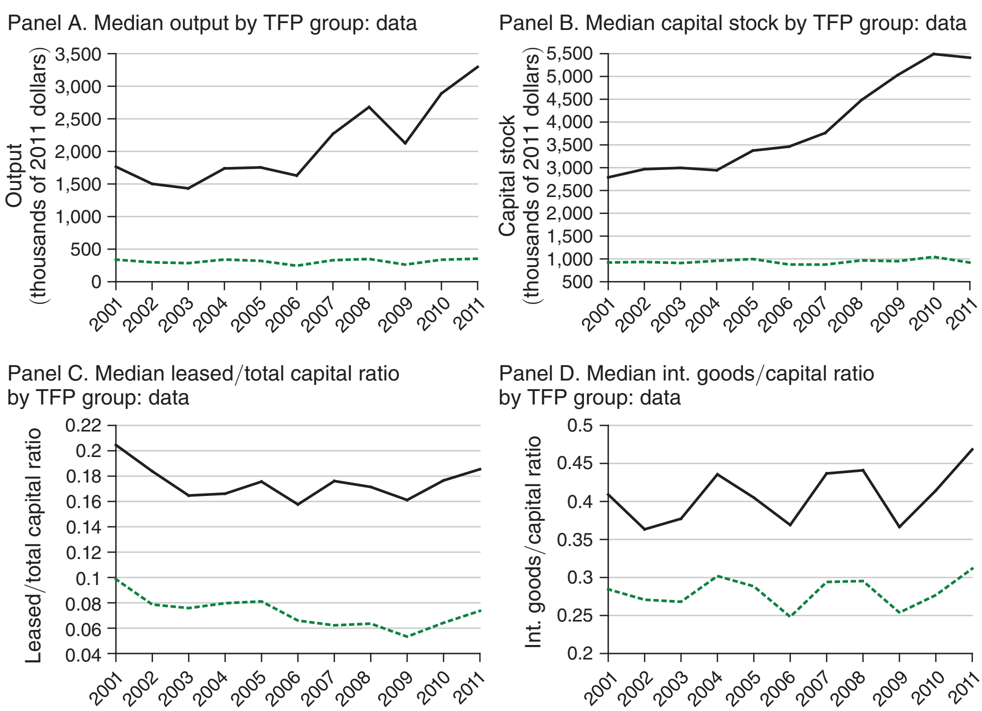

Figure 2. Production and Inputs by Productivity and Calendar Year

Notes: Thick, solid lines refer to high-productivity farms. Thinner, dashed lines refer to low-productivity farms.

Our convention will be to use thick solid lines to represent high-productivity farms and thinner dashed lines to represent low-productivity farms. Figure 2 shows output (revenues) and input choices. The top two panels show that high-productivity

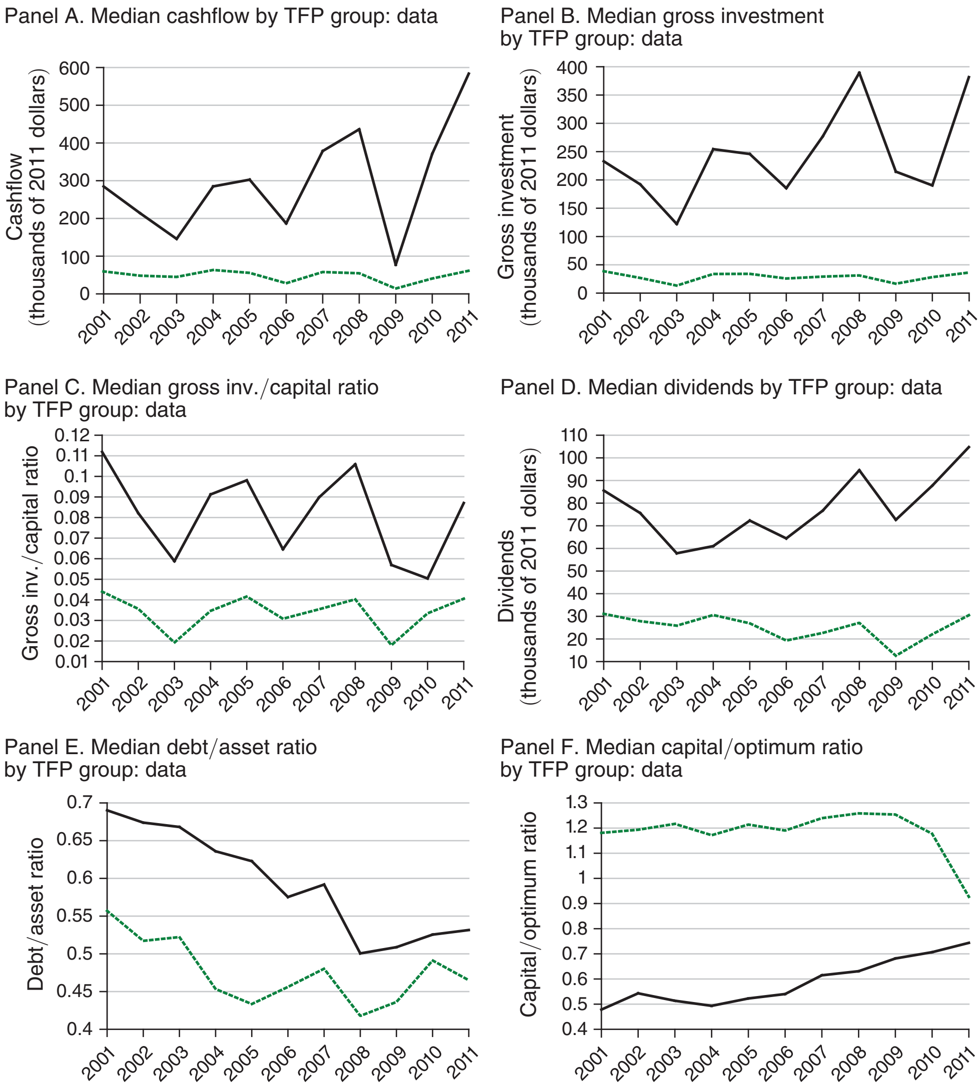

Figure 3. Investment and Finances by Productivity and Calendar Year

Notes: Thick, solid lines refer to high-productivity farms. Thinner, dashed lines refer to low-productivity farms.

farms operate at a scale several times larger than that of low-productivity farms.[15] This size advantage is increasing over time: high-productivity firms are growing while low-productivity firms are static. These differences will prove crucial to identifying our model.

Panel C shows that high-productivity farms lease a larger fraction of their capital stock (18 percent versus 8 percent). The leasing fractions are all small and

[15] Using the 2007 US Census of Agriculture, Adamopoulos and Restuccia (2014) documents that farms with higher labor productivity are indeed substantially larger.

stable, however, implying that farms expand primarily through investment. In our model we will assume that all capital is owned. Panel D shows that the ratio of variable inputs (feed, fertilizer, and hired labor) to capital is also higher for high-productivity farms (40 percent versus 30 percent). As mentioned earlier, this could be due to differing production functions between stanchion and parlor farms, given that most high-productivity farms are parlors, or financial constraints on the purchase of variable inputs. We will account for both possibilities in our model.

Figure 3 shows financial variables. The top two panels represent median cash flow and gross investment. These variables are positively correlated in the aggregate; for example, cash flow and investment both fell during the recession of 2009. Given that the aggregate shocks are not persistent, high current productivity (and cash flow) does not indicate high expected productivity. The correlation of cash flow and investment thus suggests financial constraints, which are relaxed in periods of high output prices. However, the interpretation of cash flow regressions, much less simple correlations, is notoriously difficult (see, for example, Erickson and Whited 2000 and Gomes 2001, among others). We will formally assess the importance of financial constraints using our structural model.

The middle row shows investment rates and dividend payments. High-productivity farms invest at a higher rate and pay larger dividends to their owner/operators than low-productivity farms. Dividends and cash flow are strongly correlated for both types of farms. In general, dividend flows are quite modest, especially for low-productivity farms.

Panel E of Figure 3 shows debt/asset ratios.[16] Although high-productivity farms begin the sample period with more debt, over the sample period they decrease their leverage, even as they expand their capital stocks.

In a static frictionless model, the optimal capital stock for a farm with productivity level μ_i is given by $k_i^* = \left[\kappa \exp(\mu_i)\right]^{1/\alpha}$, where κ is a positive constant.[17] Computing this optimal capital stock using the parameters we estimate in Section V, panel F of Figure 3 plots median values of the ratio k_{it}/k_i^*, showing the extent to which farms operate at their efficient scales. The median low-productivity farm holds close to the optimal amount of capital throughout the sample period. In contrast, the capital stocks of high-productivity farms are initially almost one-half of their optimal size, but grow rapidly. This difference can explain why large firms are more indebted and invest at higher rates.

While we do not seek a quantitative measure of allocative inefficiency, panel F of Figure 3 does suggest that financial constraints hinder the optimal allocation of capital. Midrigan and Xu (2014) finds that financial constraints impose their greatest distortions by limiting entry and technology adoption (see also Caggese 2019). To the extent that high-productivity farms are more likely to utilize new technologies, such as robotic milkers,[18] our results are consistent with their findings. Our results

[16] To ensure consistency with the model, and in contrast to Table 1, we add capitalized values of leased capital to both assets and liabilities.

[17] 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 the construction of capital stock described in the online Appendix, here we use a single user cost for all capital. Standard calculations show that $\kappa = (\gamma/(r+\delta-\varpi))^{\alpha+\gamma}(1-\alpha-\gamma)^{1-\alpha-\gamma} E(\exp(\Delta_t \varepsilon_{it}))$.

[18] Jesse McKinley, "With Farm Robotics, the Cows Decide When It's Milking Time," *New York Times*, April 22, 2014.

also comport with the Buera, Kaboski, and Shin (2011) argument that financial constraints are most important for large-scale technologies.[19]

On the other hand, our findings seem at odds at with the evidence from the corporate finance literature that large firms are less financially constrained (Kaplan and Zingales 1997, Whited and Wu 2006, Hadlock and Pierce 2010). This apparent discrepancy may be due to age and/or vintaging effects. Although larger farms appear more constrained, they also carry more debt. Because these farms are more likely to use parlor technologies, which are newer, they may simply have had less time to accumulate capital. It is also possible that many smaller farms cannot acquire the financing needed to install newer technologies and are thus effectively more constrained than the larger farms.[20]

II. Model

Consider a farm family seeking to maximize expected lifetime utility at "age" q:

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

where: q denotes the age of the principal (youngest) operator; d_q denotes farm "dividends" per operator; the indicator $\mathbf{1}\{\text{farm operating}\}$ equals 1 if the family is operating a farm and 0 otherwise, and χ measures the psychic/nonpecuniary gains from farming;[21] 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

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

with $\nu \geq 0$, $c_0 \geq 0$, $c_1 \geq c_0$, and $\theta \geq 1$. Given our focus on business decisions, we do not explicitly model the farmers' personal finances and saving decisions,

[19] Protracted capital stock growth could also reflect capital adjustment costs, which we rule out by assumption. Capital adjustment costs cannot generate, however, the observed positive correlation between aggregate cash flow and aggregate investment. Because the aggregate productivity shocks appear to be serially uncorrelated, we do not believe the latter relationship is caused by current cash flow acting as a signal for future productivity.

[20] We are grateful to an anonymous referee for this insight.

[21] While the existence of nonpecuniary benefits is well documented, less is known about their precise form. In the interests of simplicity, we model them as a constant increment to flow utility. A nonpecuniary benefit that varies with farm size or other attributes is plausible, but also very difficult to identify without detailed data on the farmers' outside options. For example, holding fixed the production function and the productivity level, in our model a nonpecuniary benefit that increased with firm size would imply larger farms. Our estimation procedure would offset this by lowering the returns to production and implied productivity, yielding the same production behavior.

but 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 retirement utility function adapts a specification commonly used to model bequest motives (De Nardi 2004; De Nardi, French, and Jones 2010). The scaling parameter θ reflects the notion that upon retirement, the family lives for θ years and consumes the same amount each year, while the shift term c_1 captures Social Security and other nonfarm retirement wealth.

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; r denotes the real risk-free interest rate; and, in an abuse of notation, d_q denotes the wage worker's consumption. Workers also face a standard borrowing constraint:

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

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

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

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 productivity component μ, it makes its production decisions before observing the transitory effects Δ_t and ε_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:

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

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

Because the farm enjoys limited liability, it may be able to void some of its debt via liquidation. This leads to enforceability problems of the sort described in Kehoe and Levine (1993). A family operating a farm thus makes an occupational decision at the beginning of each period. The family has three options: continued operation with full debt repayment, continued operation with reorganization, or liquidation followed by wage work.

If the family decides to repay its debt and continue operating, it will have two sources of funding: net worth, $e_q \equiv \tilde{a}_q - b_q$; and the age-$q$ proceeds from 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:

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

Combining the previous two equations yields

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

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; withdrawals from cash reserves, contained in the second set of brackets; and additional borrowing, contained in the third set of brackets.

Operating farms face three financial constraints:

$$\psi b_{q+1} \leq k_q, \tag{8}$$

$$n_q \leq \zeta \ell_q, \tag{9}$$

$$d_q \geq -c_0, \tag{10}$$

with $\psi \geq 0$ and $\zeta \geq 1$. The first of these constraints, given by equation (8), is a collateral constraint of the sort introduced by Kiyotaki and Moore (1997). Larger values of ψ imply a tighter constraint, with farmers more dependent on equity funding. The second constraint, given by equation (9), is a cash-in-advance or working capital constraint (Jermann and Quadrini 2012). Larger values of ζ imply a more relaxed constraint, with farmers more able to fund operating expenses out of contemporaneous revenues. Because dairy farms receive income throughout the year, in an annual model ζ is likely to exceed 1. The third constraint, given by equation (10), limits the farm's ability to raise funds by issuing new equity. We also require that

$$b_{q+1} \geq 0. \tag{11}$$

However, we allow farms to build up buffer stocks in the form of excess cash.

As alternatives to continued operation and full repayment, a farm can reorganize or liquidate. If it chooses the second option, reorganization, some of its debt is written down.[22] The debt liability b_q is replaced by $\hat{b}_q \leq b_q$, and the restructured farm continues to operate. Finally, if the family decides to exit, the third option, the farm

[22] 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) reviews the bankruptcy options available to farmers.

is liquidated and assets net of liquidation costs (up to debt outstanding) are handed over to the bank. The family then exits to wage work, with assets a_q, where

$$a_q = \max\{(1-\lambda)\tilde{a}_q - b_q, 0\}.$$

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 or if an ongoing operation decides to reduce its capital stock. While we allow the family to roll over debt (b_q can be bigger than $\tilde{a}_q$), Ponzi games are ruled out by requiring all debts to be resolved at retirement,

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

The interest rate realized on debt issued at age $q-1$, $\hat{r}_q = \hat{r}_q(s_q, r_q)$, depends on the state vector s_q (specified below) and the contractual interest rate r_q. If the farmer chooses to repay his debt in full, $\hat{r}_q = r_q$. If the farmer chooses to default,

$$\hat{r}_q = \frac{\min\{(1-\lambda)\tilde{a}_q, b_q\}}{b_q/(1+r_q)} - 1 = (1+r_q)\frac{\min\{(1-\lambda)\tilde{a}_q, b_q\}}{b_q} - 1.$$

The return on restructured debt is $\hat{r}_q = (1+r_q)\hat{b}_q/b_q - 1$. We assume that loans are supplied by a risk-neutral competitive banking sector, so that

$$E_{q-1}\left(\hat{r}_q(s_q, r_q)\right) = r, \tag{12}$$

where r is the risk-free rate.

The decision to default or renegotiate is best expressed recursively. To simplify matters, we assume that the decision to work for wages is permanent, so that the worker's only decision is how much to save. The value function for a worker is thus

$$V_q^W(a_q) = \max_{0 \leq d_q \leq (1+r)a_q + w} u(d_q) + \beta V_{q+1}^W(a_{q+1}), \qquad \text{subject to (3)}.$$

A family that has decided to fully repay its debt and continue farming chooses how much income to withdraw from the farm (d_q) and how much new debt (b_{q+1}) to issue. It then allocates its financial resources between capital (k_q) and cash (ℓ_q). The cash, along with revenues earned as the year proceeds, are used to buy intermediate goods (n_q). The resulting value function is

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

$$\text{subject to (4)–(6), (8)–(12),}$$

where $V_q(\cdot)$ denotes the continuation value prior to the age-q occupational choice:

$$V_q(\tilde{a}_q, b_q, \mu) = \max_{\{V^F, V^W\}} \Big\{ V_q^F\big(\tilde{a}_q - \min\{b_q, \hat{b}_q\}, \mu\big), \\ V_q^W\big(\max\{(1-\lambda)\,\tilde{a}_q - b_q, 0\}\big) \Big\}.$$

The renegotiated debt level, $\hat{b}_q$, can then be expressed as

$$\hat{b}_q = \max\{b_q^*, (1-\lambda)\,\tilde{a}_q\},$$

$$V_q^F(\tilde{a}_q - b_q^*, \mu) \equiv V_q^W\big(\max\{(1-\lambda)\,\tilde{a}_q - b_q, 0\}\big),$$

so that $\hat{b}_q = \hat{b}_q(s_q)$, with $s_q = \{\tilde{a}_q, b_q, \mu\}$. The first line of the definition ensures that $\hat{b}_q$ is incentive-compatible for lenders: the bank can always force farms into liquidation, bounding $\hat{b}_q$ from below at $(1-\lambda)\,\tilde{a}_q$. However, if operators find liquidation and exit sufficiently unpleasant, the bank may be able to extract a value b_q^*, that is even larger. The second line ensures that such a payment is incentive-compatible for farmers, i.e., b_q^* is set so that farmers are indifferent between continued operation with equity level $\tilde{a}_q - b_q^*$ and liquidation followed by wage work. Holding fixed initial net worth, $\tilde{a}_q - b_q$, b_q^* will be largest when the farm is highly productive (μ is large), or when the liquidation cost $\lambda\,\tilde{a}_q$ is large.

We assume that once a farm chooses to renegotiate its debt, the bank holds all the bargaining power. At this point, the farm can only accept the offered value of $\hat{b}_q$ or liquidate. It follows that $\hat{b}_q$ can be larger than b_q, and only farms with low productivity and/or low net worth will find it worthwhile to reorganize.

Solving for $\hat{b}_q = \hat{b}_q(s_q)$ allows us to express the finance/occupation indicator $I_q^B \in$ {continue, restructure, liquidate} as the function $I_q^B(s_q)$. We can then divide the farm's optimal repayment amount by the loan's face value and compare the realized return on the loan, $\hat{r}_q(s_q, r_q)$, to the contractual interest rate r_q:

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

Inserting this result into equation (12), we can calculate the equilibrium contractual rate as[23]

$$(13) \qquad 1 + r_q = [1 + r]/E_{q-1}\left(\frac{1 + \hat{r}_q(s_q, r_q)}{1 + r_q}\right).$$

A key feature of our model is limited liability. Dividends are bounded below by $-c_0$, the estimated value of which is small, limiting the amount the bank can

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

extract through renegotiation. If the farm liquidates, the bank at most receives $(1-\lambda)\tilde{a}_q$. Coupled with the option to become a worker, limited liability will likely lead the continuation value function, $V_q(\cdot)$, to be convex over the regions of the state space where farming and working have similar valuations (Vereshchagina and Hopenhayn 2009).

III. 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 \$15,000, or 2,000 hours at \$7.50 an hour. As we show in Section VII, the choice of w is largely a normalization of the occupation utility parameter χ. From the DFBS data we estimate the capital depreciation rate δ to be 5.55 percent and the appreciation rate ϖ to be 3.56 percent, as described in the online Appendix. The liquidation loss, λ, is set to 35 percent. This is at the upper range of the estimates found by Levin, Natalucci, and Zakrajšek (2004). Given that a significant portion of farm assets are site-specific, high loss rates are not implausible. We discuss a specification with $\lambda = 0.175$ in Section VII.

In the second step, we estimate the parameter vector $\Omega = (\beta, \nu, c_0, \chi, c_1, \theta, \alpha, \gamma, \zeta, \psi)$ 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 91 and 92 cows per operator. As Section I suggests, this measure corresponds closely to the fixed productivity component μ_i. Then for each of these four age-size cells, for each of the years 2001 to 2011, we match the following sample statistics:

(i) The median value of capital per operator, k.

(ii) The median value of the output-to-capital ratio, y/k.

(iii) The median value of the variable input-to-capital ratio, n/k.

(iv) The median value of the gross investment-to-capital ratio, i/k.

(v) The median value of the debt-to-asset ratio, $b/\tilde{a}$.

(vi) The median value of the cash-to-asset ratio, $\ell/\tilde{a}$.

(vii) The median value of the dividend growth rate, d_t/d_{t-1}.[24]

(viii) The fraction of farms operating and observed in the DFBS.

When possible, we match medians rather than means, so that extreme realizations of firm-specific ratios, due mostly to small denominator values, do not distort our targets.

For each value of the parameter vector Ω, we find the SMD criterion as follows. First, we use α and γ 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, along with estimates of the standard deviations of Δ_t, and ε_{iq} for use in finding the model's decision rules. Using a bootstrap method, we take repeated draws from the empirical 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 calendar year it is first observed. At the same time we draw ϑ_i, the list of dates that farm i is observed in the DFBS.

Discretizing the asset, debt, equity, and productivity grids, we use value function iteration 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 the initial state vector s_{j0}, the observation indicator ϑ_j, and the shock histories $\{\Delta_t, \varepsilon_{jt}\}_t$. The residual shocks $\{\varepsilon_{jt}\}_{jt}$ are produced with a random number generator, assuming a normal distribution and using the standard deviation of ε_{iq} described immediately above. The aggregate shocks are those observed in the DFBS. Combining these shocks with the decision rules allows us to compute that farm's history for the DFBS sample period. We then construct summary statistics for the artificial data in the same way we compute them for the DFBS. Let g_{mt}, $m \in \{1, 2, \ldots, M\}$, $t \in \{1, 2, \ldots, T\}$, denote the realization of summary statistic m in calendar year t, such as median capital for young, large farms in 2007. The model-predicted value of g_{mt} is $g^*_{mt}(\Omega)$. We estimate the model by minimizing the squared proportional differences between $\{g^*_{mt}(\Omega)\}$ and $\{g_{mt}\}$:

$$\sum_{m=1}^{M} \aleph_m \sum_{t=t_1}^{T} \left(\frac{g^*_{mt}(\Omega)}{g_{mt}} - 1 \right)^2,$$

where $\aleph_m$ denotes the weight placed on the mth set of differences. Our estimate of the "true" parameter vector Ω_0 is the value of Ω that minimizes this criterion. The online Appendix contains a detailed description of how we calculate standard errors.

An important concern is accounting for attrition in the DFBS. When a farm does not participate in the DFBS, the reason is not recorded. The farm may have exited the industry, or it may simply have chosen not to participate. A number of farms exit and reenter the dataset. To handle this ambiguity, when data for a particular farm-year are missing in the DFBS, we treat them as missing in the simulations, using the appropriate draw of ϑ_j. The simulated data panel therefore has an unbalanced structure

[24] Because profitability levels, especially for large farms, are sensitive to total returns to scale $1 - \alpha$, we match dividend growth, rather than levels. Both statistics measure the desire of farms to smooth dividends, which in turn affects their ability to fund investment through retained earnings.

similar to that in the DFBS. On the other hand, the model gives farmers the option to become workers. If a simulated farm exits the industry we treat it as unobserved, even if its data counterpart (with the same values of s_0 and ϑ) is observed. As a result the model may generate less DFBS participation than is observed. The final set of statistics in the SMD criterion (item (viii) above), which relate to DFBS participation, discipline the model along this dimension. "Counterfactual exit" will increase our SMD criterion, as the model-predicted DFBS participation rates will be smaller than those observed in the data.

The need to match DFBS participation also informs our choice of the weights $\{\aleph_m\}$. All of these weights are set to 1, except for the weight for DFBS participation, $\aleph_8$, which is set to 25. Without the higher weight, some versions of the model estimated in the robustness checks (especially those with the nonpecuniary benefit set to zero) significantly understate DFBS participation. We use the higher weight in all specifications, including the baseline, for consistency.

IV. Parameter Estimates, Goodness of Fit, and Identification

A. *Parameter Estimates*

Column 1 of Table 4 shows the parameter estimates and asymptotic standard errors for the baseline specification. The estimated values of the discount factor β, 0.973, and the risk aversion coefficient ν, 4.34, are both within the range of previous estimates (see, e.g., the discussion in De Nardi, French, and Jones 2010). The retirement parameters imply that farms greatly value post-retirement consumption; in the period before retirement, farmers consume only 0.95 percent of their wealth and save the rest.[25]

The nonpecuniary benefit of farming, χ, is expressed as a consumption decrement to the nonfarm wage w. Mechanically, we set

$$\chi = \frac{1}{1-\nu}(c_0 + w)^{1-\nu} - \frac{1}{1-\nu}(c_0 + w - \chi_C)^{1-\nu}$$

and estimate (and report) χ_C. This quantity can be interpreted as the equivalent variation for a switch from farming to wage work: how much consumption would a farmer surrender to avoid this switch? With w equal to \$15,000, the estimates imply that the nonpecuniary benefit from farming would offset a \$6,300 (42 percent) drop in consumption. Given the high value of ν, this translates into a large drop in utility. Even though the outside wage is modest, the income streams of low-productivity farms are so small and uncertain that some operators would exit if they did not receive significant nonpecuniary benefits.

The returns to management and capital are both fairly small, and imply that the returns to intermediate goods, $1 - \alpha - \gamma$, are between 70 and 77 percent. Table 1 shows that variable inputs in fact equal about 78 percent of revenues.

[25] This can be found by solving for optimal retirement wealth in the penultimate period of the operator's economically active life, $a^r(x) = \operatorname{argmax}_{a^r \geq 0}\left\{(1/(1-\nu))(c_0 + x - a^r)^{1-\nu} + \beta(\theta/(1-\nu))\left(c_1 + \left(a^r(1+r)/\theta\right)\right)^{1-\nu}\right\}$, and calculating $\partial a^r(x)/\partial x|_{a^r(x)>0}$. A derivation based on a similar specification appears in De Nardi, French, and Jones (2010).

Table 4—Parameter Estimates

Parameter description		Baseline (1)	$\chi = 0$ (2)	$\psi = 0$ (3)	$\nu = 0$ (4)	$\lambda = 0.175$ (5)	$w = \$30K$ (6)	No renegotiation (7)
Discount factor	β	0.973	1.000	1.001	0.967	0.973	0.973	0.98
		(0.011)	(0.008)	(0.015)	(0.002)	(0.013)	(0.010)	(0.009)
Risk aversion	ν	4.341	4.695	4.731	0	4.339	4.342	4.143
		(0.140)	(0.140)	(0.270)	(NA)	(0.181)	(0.179)	(0.109)
Consumption utility shifter (in \$000s)	c_0	3.666	1.845	3.103	1.147	3.666	3.665	3.827
		(0.149)	(0.112)	(0.196)	(7.4×10^4)	(0.259)	(0.209)	(0.230)
Retirement utility shifter (in \$000s)	c_1	16.23	22.39	18.22	0	16.23	16.23	16.73
		(0.424)	(0.396)	(0.736)	(NA)	(0.504)	(0.432)	(0.534)
Retirement utility intensity	θ	108.1	65.24	65.19	0	108.1	108.2	125.2
		(2.73)	(1.33)	(1.89)	(NA)	(3.62)	(3.20)	(3.82)
Nonpecuniary value of farming (consumption decrement in \$000s)	χ_C	6.296	0	4.002	13.510	7.259	21.884	9.227
		(0.283)	(NA)	(0.480)	(0.173)	(0.653)	(0.619)	(0.420)
Returns to management: stanchions	α	0.126	0.170	0.159	0.129	0.126	0.126	0.130
		(0.002)	(0.002)	(0.002)	(0.0005)	(0.002)	(0.001)	(0.001)
Returns to management: parlors	α	0.113	0.211	0.178	0.106	0.113	0.113	0.114
		(0.002)	(0.004)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)
Returns to capital: stanchions	γ	0.177	0.176	0.163	0.144	0.177	0.177	0.191
		(0.004)	(0.003)	(0.003)	(0.001)	(0.005)	(0.004)	(0.005)
Returns to capital: parlors	γ	0.121	0.107	0.110	0.118	0.121	0.121	0.123
		(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
Strength of collateral constraint	ψ	1.031	0.961	0	1.083	1.030	1.030	1.06
		(0.015)	(0.008)	(NA)	(0.006)	(0.015)	(0.013)	(0.019)
Degree of liquidity constraint	ζ	2.641	2.434	2.79	2.600	2.641	2.641	2.503
		(0.036)	(0.055)	(0.058)	(0.015)	(0.040)	(0.037)	(0.045)

Note: Standard errors in parentheses.

The collateral constraint parameter ψ is 1.03, implying that each dollar of debt must be backed by a roughly equivalent amount of capital. By way of comparison, Evans and Jovanovic (1989) estimates a value of ψ of at least 2.37, Buera (2009) estimates ψ to be 1.26 in the constrained version of his model and 101 in the unconstrained version, and Herranz, Krasa, and Villamil (2015) calibrates ψ to be 5.65.[26] Given that the first two studies analyze the decision to become an entrepreneur, rather than the behavior of established business, it is not surprising that they find more stringent constraints. Similarly, Herranz, Krasa, and Villamil (2015) works with the Survey of Small Business Finances (SSBF). Although SSBF respondents are established businesses, many are quite small and likely have less access to debt than our farms.

The liquidity constraint parameter ζ is estimated to be about 2.64, implying that farms need to hold liquid assets equal to about 4.5 months of expenditures. Although the collateral and liquidity constraints together significantly reduce the risk of insolvency, farms with adverse cash flow may find themselves extremely illiquid.

[26] Evans and Jovanovic (1989) and Buera (2009) do not estimate ψ itself, but the parameter constraint $k \leq \phi a$. Assuming that capital is the sum of debt and assets, $k = a + b$, we have $\psi = \phi/(\phi - 1)$. Herranz, Krasa, and Villamil (2015) works with the constraint $b \leq va$, with $\psi = (v+1)/v$.

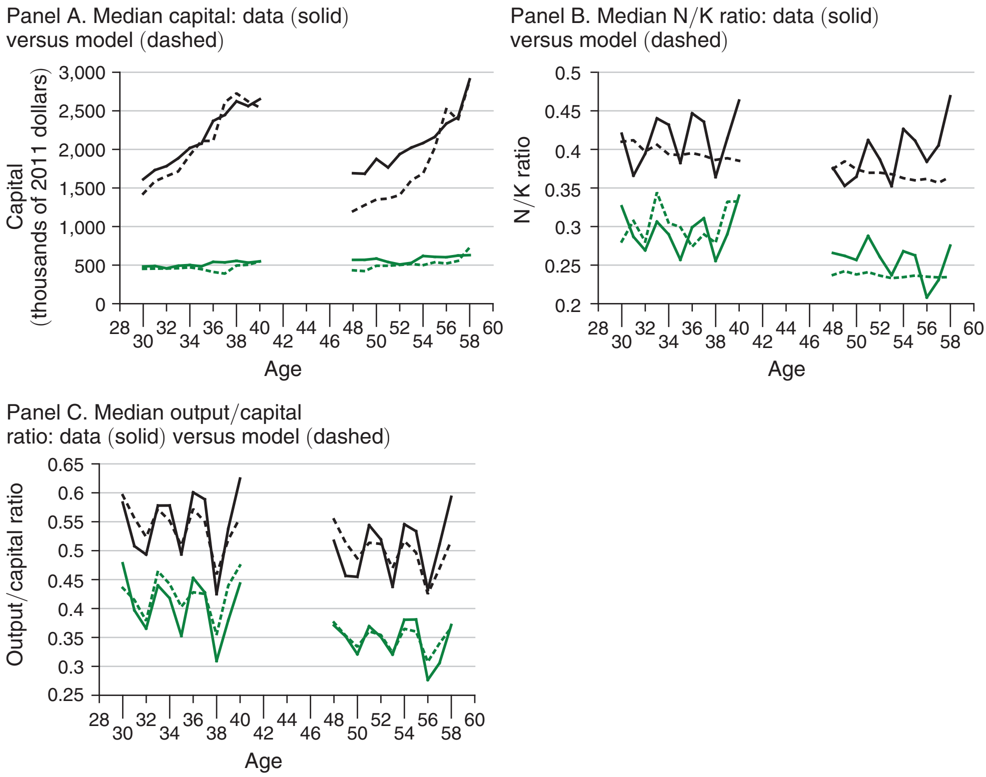

FIGURE 4. MODEL FITS: PRODUCTION MEASURES

Notes: Solid lines refer to DFBS data, dashed lines to model simulations. Thicker black lines refer to farms with large herds, thinner green lines refer to farms with small herds.

B. *Goodness of Fit*

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 30: this is the average age of the youngest operator in the junior cohort in 2001. Observations for age 31 correspond 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 well, capturing many of the differences between large and small farms and much of the year-to-year variation. Our estimation criterion also penalizes "false exits," simulated farms that exit when their data counterparts do not. False exit is uncommon, with a frequency of 0.04 percent.

We also assess the model's fit of a number of untargeted cross-sectional moments. As shown in the online Appendix, the model does a satisfactory job along this dimension as well. One exception is that the model significantly underpredicts dividend volatility. Mechanically, this occurs because the model needs a large value of ν to ensure low dividend growth. It could be the case that unobserved nonfarm resources accommodate short-term dividend movements. However, Figure 5 shows that the model also understates the dividend response to aggregate shocks, which

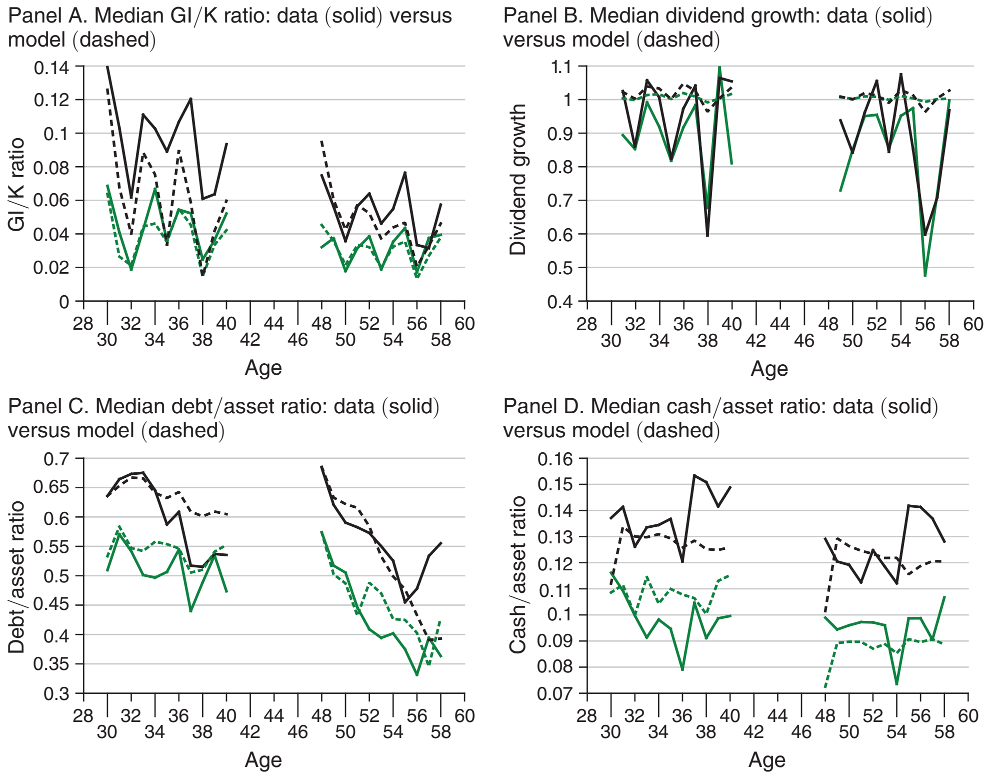

Figure 5. Model Fits: Financial Measures

Notes: Solid lines refer to DFBS data, dashed lines to model simulations. Thicker black lines refer to farms with large herds, thinner green lines refer to farms with small herds.

are removed in the cross-sectional volatility calculations. This suggests that our estimated value of risk aversion is too large.[27]

C. *Identification*

Although all of the simulated moments depend on multiple model parameters, identification is straightforward for some parameters. The production coefficients α and γ are identified by expenditure shares and the extent to which farm size varies with productivity. The cash constraint ζ is identified by the observed cash/asset ratio. The parameter χ is identified by the counterfactual exit that would occur in its absence. The parameter ψ, measuring the strength of the collateral constraint, is identified by three features of the data: (i) high-productivity farmers expand their capital stock steadily over time, rather than all at once; (ii) for farms of all sizes, years of high income are years of high investment; and (iii) the evolution of the debt-asset ratio.

[27] An alternative specification using Epstein-Zin (1989) preferences to separate risk aversion and intertemporal substitutability did not significantly increase dividend volatility.

TABLE 5—COMPARATIVE STATICS (WEIGHTED BY HERD SIZE)

	Fraction operating[a]	Assets	Debt	Capital	Optimal capital
Panel A					
1. Baseline model	1.000	947	479	781	1,212
2. $\beta = 0.95$	1.000	928	475	762	1,212
3. $\nu = 0.0$	0.897	1,227	615	1,051	1,338
4. $\nu = 6.0$	1.000	922	454	754	1,212
5. $c_0 = 200$	1.001	953	539	787	1,211
6. $c_0 = 0$	1.000	938	471	771	1,212
7. $\chi = 0$	0.805	1,109	585	910	1,456
8. $\lambda = 0$	0.960	964	486	799	1,170
9. $\lambda = \chi = 0$	0.615	1,280	708	1,082	1,694
10. $\psi = 0.5$	1.001	1,150	675	983	1,211
11. $\psi = 1.5$	1.000	733	278	564	1,212
12. $\zeta = 1$	0.984	819	367	567	1,219
13. $\zeta = 6$	1.000	1,000	524	883	1,212
14. No aggregate shocks	1.000	961	498	796	1,212
15. No transitory shocks	1.000	989	531	825	1,212
	Debt/assets[b]	Cash/assets[b]	N/K[b]	Investment/capital[b] (percent)	Dividend growth rate[c] (percent)
Panel B					
1. Baseline model	0.506	0.107	0.307	6.15	1.88
2. $\beta = 0.95$	0.512	0.105	0.309	5.86	1.68
3. $\nu = 0.0$	0.501	0.108	0.310	7.89	15.33
4. $\nu = 6.0$	0.493	0.109	0.308	6.18	1.89
5. $c_0 = 200$	0.565	0.105	0.313	5.59	3.08
6. $c_0 = 0$	0.502	0.108	0.307	6.20	2.00
7. $\chi = 0$	0.528	0.108	0.314	6.78	2.35
8. $\lambda = 0$	0.504	0.108	0.305	5.94	1.45
9. $\lambda = \chi = 0$	0.553	0.111	0.320	6.31	2.12
10. $\psi = 0.5$	0.587	0.112	0.304	2.87	0.85
11. $\psi = 1.5$	0.379	0.112	0.339	7.61	2.44
12. $\zeta = 1$	0.448	0.216	0.297	6.60	2.15
13. $\zeta = 6$	0.524	0.057	0.311	5.89	1.71
14. No aggregate shocks	0.518	0.108	0.308	6.06	2.01
15. No transitory shocks	0.537	0.109	0.309	6.27	1.92

Notes:
[a] Relative to baseline case
[b] Ratios of averages
[c] Mean growth rates for annual averages

The identification of other parameters is more complicated and best illustrated through comparative statics. Table 5 shows averages of model-simulated data over the 11-year (pseudo-) sample period. Row 1 in both panels shows statistics for the baseline model associated with the parameters in column 1 of Table 4, while subsequent rows show the statistics that result from varying different parameters or features of the model. In all the counterfactual experiments we use herd size weights, so that the averages are (roughly) representative of New York State. Our qualitative conclusions do not depend on the weights.

Row 2 describes the effects of lowering the discount factor β to 0.95. Panel A shows that farms hold less capital, invest less, and take on more debt, as they place less weight on future returns. Dividends grow more slowly (panel B), with the average growth rate falling from 1.88 to 1.68 percent.

Row 3 shows the effects of setting the curvature parameter ν to zero, so that preferences are linear in dividends. Linearity leads farmers to invest more aggressively

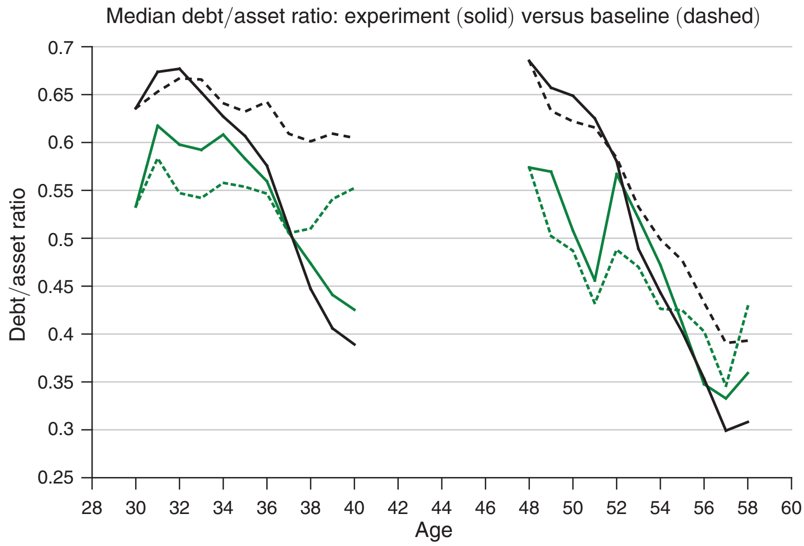

Figure 6. The Effects of Imposing Linear Utility on the Debt/Asset Ratio

Notes: Solid lines refer to model simulations with $\nu = 0$, dashed lines to baseline simulations. Thicker lines refer to farms with large herds, thinner lines refer to farms with small herds.

in capital, as they are less concerned about uncertain returns and more willing to defer consumption. The average investment rate rises significantly, while the capital stock increases from \$0.78 to \$1.05 million. Farms pay for this additional capital in several ways. Dividends are initially small, as the farmers raise funds internally. Borrowing is also higher. However, as Figure 6 shows, farms also deleverage faster in later years, since the borrowing rate $r = 0.04$ exceeds the discount rate of 0.027, and the opportunity cost of retained earnings, unsmoothed dividends, is zero.[28]

Row 4 shows the effects of raising ν from 4.34 to 6. Relative to the baseline case, the dividend growth rate is lower, as farms withdraw more funds up front. Debt is also lower, perhaps for precautionary reasons. The result is that the capital stock is lower in every period: the average stock falls from \$0.78 to \$0.75 million.

Row 5 shows the effects of increasing the utility shifter c_0 to 200.[29] In addition to serving as a preference parameter, c_0 limits the ability of farms to raise funds from equity injections. A value of c_0 of 200 thus allows farmers to inject up to \$200,000 of personal funds into their farms each year. Capital and assets increase, as panel A shows. Average dividends grow more quickly, as equity injections imply low initial dividends (panel B). Finally, increasing c_0 reduces risk aversion, encouraging farms to take on more debt. Row 6 shows the effects of changing c_0 in the opposite direction, to 0. Most variables move in the directions opposite to those in row 5.

[28] Row 3 also shows that the number of operating farms fall. This is an artifact of how we calculate the nonpecuniary benefit. When preferences are linear in consumption, the utility value of a \$6,300 drop in consumption is much smaller than in the baseline specification. With small nonpecuniary benefits, unproductive farms have less incentive to operate.

[29] We also increase the retirement shifter c_1 by an equivalent amount.

Because the discount factor β, the risk coefficient ν, and the utility shifter c_0 affect similar summary statistics (dividend growth, capital, and debt) identification occurs jointly. It is informative to consider the simple unconstrained Euler equation,

$$(c_0 + d_t)^{-\nu} = \beta(1 + \iota_{t+1})(c_0 + d_{t+1})^{-\nu},$$

where ι denotes the returns the farm enjoys on its capital expenditures. An important feature of the data is that the average dividend growth rate is modest for both small and large farms. Moreover, because large farms are expanding while small farms are not, the model requires that the marginal product of capital be higher in large operations, to justify the different capital stock trajectories. This means that large farms have higher values of ι_{t+1}. In order for both types of farms to have flat dividend trajectories, ν must be large and c_0 must be small. Given this requirement, the parameters further adjust to help the model match capital and debt. Another useful distinction is that raising c_0, which increases the scope for equity injections, is more effective in allowing farmers to acquire capital up front than is lowering ν. While the capital stock rises relative to the baseline in both rows 3 and 5, the investment rate rises significantly in row 3 but falls in row 5.

The retirement parameters c_1 and θ are identified by life-cycle variation not shown in Table 5. As θ goes to 0 and retirement utility vanishes, older farmers will have less incentive to invest in capital, and their capital stock will fall relative to that of younger farmers. Setting θ to 0 also increases indebtedness, as farmers raise their average dividend (not shown) by over 50 percent.

V. Model Mechanisms

Our model has three main features: nonpecuniary benefits, financial constraints, and risk aversion. In this section we explore how these mechanisms work. First, we use a set of comparative statics exercises to understand the effects of each mechanism. We then reestimate the model, shutting down each of the mechanisms in turn, to further understand their implications and to highlight the importance of estimating them all jointly.

A. *Nonpecuniary Benefits*

Our estimates imply that the nonpecuniary benefit from farming is equivalent to the flow utility lost by decreasing consumption from \$15,000 to \$8,700. The parameter χ is identified by occupational choice, namely the estimation criterion that farms observed in the DFBS in a given year also be operating and thus observed in the simulations. Row 7 of Table 5 shows the effects of setting χ to 0. In the absence of nonpecuniary benefits more farms liquidate, so that the average number of operating farms drops by 9 percent. Not surprisingly, it is the smaller, low-productivity farms that exit: the survivors in row 7 have more assets, debt, and capital. Their optimal capital stock (which is directly proportional to productivity) rises from \$1.21 to \$1.46 million. Hamilton (2000) and Moskowitz and Vissing-Jørgensen (2002) find that many entrepreneurs earn below-market returns, suggesting that nonpecuniary benefits are large (also see Quadrini 2009 and Hall and Woodward 2010).

Similarly, Figure 3 shows that many low-productivity farms have dividend flows around the outside salary of \$15,000. Moreover, these flows are uncertain, while the outside salary is not. This is consistent with a high value of χ.

The high value of χ may reflect other considerations, such as efficiencies in home production or tax advantages.[30] It may also be the case that farm income is underreported (Herrendorf and Schoellman 2015). Furthermore, although \$15,000 is roughly equivalent to the Federal Poverty Line for a two-person household, it may overstate the outside earnings available to farmers. Poschke (2012, 2013) documents that the probability of entrepreneurship is U-shaped in an individual's prior wage, and argues that many low-productivity entrepreneurs start and maintain their businesses because their outside options are even worse. Herrendorf and Schoellman (2018) concludes that the low wages of agricultural workers reflect low levels of human capital.

On the other hand, there is considerable direct evidence suggesting that farming, and entrepreneurship in general, provides large nonpecuniary rewards. Recent surveys of national well-being, published by the Office for National Statistics in the United Kingdom, show that the levels of life satisfaction of farmers and farm workers rank among the highest for all occupations and are substantially higher than the levels of life satisfaction reported by individuals in occupations with similar incomes such as construction and telephone sales (O'Donnell et al. 2014). Looking across all sectors, Hurst and Pugsley (2011, p.73) finds that nonpecuniary considerations "play a first-order role in the business formation decision" and that many small businesses have "no desire to grow big"(p.75). Both attitudes appear consistent with the behavior of the small farms in our sample.

B. *Financial Constraints*

Our model contains three important financial frictions: liquidation costs, collateral constraints, and liquidity constraints. We consider the effects of each element on assets, debt, capital, investment, and exit.

Liquidation Costs.—Row 8 of Table 5 shows the effects of setting the liquidation cost λ to 0. Eliminating the liquidation cost *reduces* the number of operating farms by allowing farmers to retain more of their wealth after exiting.[31] Liquidation costs thus provide another explanation of why entrepreneurs may persist despite low financial returns. The effect of setting $\lambda = 0$ is in many ways similar to that of eliminating the nonpecuniary benefit χ. This lack of identification is one reason why we calibrate rather than estimate λ. Row 9 shows that nonpecuniary benefits and liquidation costs reinforce each other; setting $\lambda = \chi = 0$ leads nearly 40 percent of the farms to exit.

Comparing row 8 to row 1 shows that the farms that remain after removing the liquidation cost have more capital and assets, but are not more productive. This

[30] For example, farmers may be able to report (or misreport) personal consumption, such as the use of a farm vehicle, as operating expenditures. We are indebted to Todd Schoellman and an anonymous referee for this point.

[31] The net effect of liquidation costs on the number of farms also depends on entry, which we do not model. Eliminating the liquidation cost would likely encourage entry.

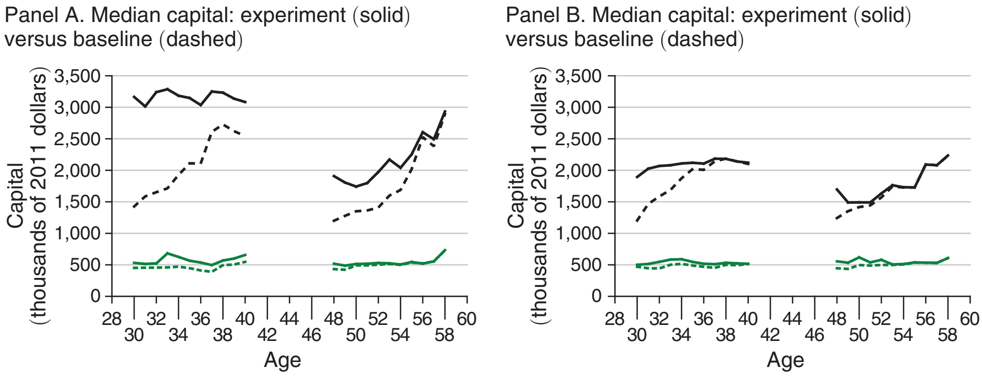

Figure 7. The Effects of Relaxing the Collateral Constraint on the Capital Stock

Notes: Solid lines refer to model simulations with $\psi = 0.5$, dashed lines to baseline simulations. Thicker lines refer to farms with large herds, thinner lines refer to farms with small herds. Panel A shows results for the baseline model, panel B shows results for the model estimated with the nonpecuniary benefit set to 0.

suggests that the collateral and liquidity constraints reduce the profitability of some productive farms. However, comparing row 9 to row 7 shows that in the absence of nonpecuniary benefits, the farms that remain after removing the liquidation costs are significantly more productive. Liquidation costs can thus generate financial inefficiency, by discouraging the reallocation of capital and labor to more productive uses.

Collateral Constraints.—Row 10 shows the effects of setting the collateral constraint ψ to 0.5, allowing each dollar of capital to back up to \$2 of debt. Farms respond to the relaxed constraint by borrowing more and acquiring more capital, with mean capital rising from \$1.60 million to \$2.00 million. Much of this additional capital is purchased up front; the investment rate falls from 6.2 percent to 2.9 percent. Panel A of Figure 7, which compares capital stock trajectories, shows that the increase in initial capital is concentrated in the large/high-productivity farms, suggesting again that borrowing constraints misallocate capital across farms.

Row 11 of Table 5 shows the effects of the opposite experiment, setting ψ to 1.5. Tightening the constraint this much leads farms to drastically reduce their capital stock, by nearly 28 percent of its baseline value, as panel A shows. Farms now accumulate their capital through retained earnings. With capital more difficult to finance, farms use more intermediate goods, so that the fall in output, 20 percent, is smaller than the fall in capital.

Liquidity Constraints.—Rows 12 and 13 of Table 5 illustrate the effects of the liquidity constraint, given by equation (9). Row 12 shows what happens when we tighten this constraint by reducing ζ to 1. Even though fewer farms remain in business, the average scale of operations declines. While total assets fall by around 13 percent, capital falls by nearly 28 percent (panel A), and the cash/asset ratio jumps from 0.107 to 0.216 (panel B). 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. Output falls by 27 percent.

Loosening the liquidity constraint ($\zeta = 6$) allows farms to hold a larger fraction of their assets in productive capital, raising the assets' overall return. Total assets rise from their baseline value by 5.6 percent, while capital rises even more, by 13.1 percent.

C. *Risk Aversion*

Our estimates suggest that our entrepreneurs are quite risk averse, with a coefficient of relative risk aversion (ν) of about 4.34. This parameter is identified by the low observed dividend growth rates, as higher values of ν make entrepreneurs less willing to substitute dividends across time. Table 5 shows that linear utility would lead farmers to choose extremely small dividends at the beginning of the estimation period, resulting in counterfactually high dividend growth.

Section I showed that farmers face significant uninsured risk, both aggregate and idiosyncratic. Aggregate risk is in turn closely related to milk price fluctuations. This suggests a potentially useful role for government programs to insure farmers against these fluctuations, as envisaged by various dairy support programs.[32] In Section VI below, we analyze the effects of the specific provisions of the 2014 Farm Bill, but in this section we examine the effects of aggregate and idiosyncratic risk in general.

Comparing row 14 of Table 5 to the baseline model in row 1 shows the effects of shutting down aggregate risk, keeping mean productivity constant. Such a change can be viewed as the introduction of complete insurance against aggregate shocks. Farms expand operations by increasing debt, and using it to finance purchases of both fixed and variable inputs. The average capital stock increases by about 1.9 percent. This increase is modest, as the farms are still subject to idiosyncratic shocks and operators are risk averse.

Like the aggregate shock, the idiosyncratic shock is also i.i.d. and has a similar standard deviation (6 percent compared to 7 percent for the aggregate shock). Row 15 shows that the effects of eliminating all transitory shocks (aggregate and idiosyncratic) are larger, but qualitatively similar, to the results shown in row 14. The average operation increases its capital stock by almost 5.7 percent and its debt by nearly 11 percent.

It is worth noting that the elimination of transitory risk, aggregate or idiosyncratic, has little effect on the extensive margin. The fraction of farms operating is virtually unchanged, as is their time-invariant productivity level, as measured by the optimal capital stock.

Rows 14 and 15 suggest that risk discourages investment, as reducing risk leads to higher capital. In addition to risk aversion, financial incentives induce farms to behave this way. Although our model includes limited liability and occupational choice, most low-productivity farms enter our sample with low levels of indebtedness and (relative to the productivity fixed effect μ_i) high capital stocks (see Figures 2 and 3). In such circumstances the risk-taking incentives described by Vereshchagina and Hopenhayn (2009) are less likely to apply. Vereshchagina and Hopenhayn also argue that patient firms are less likely to seek risky investment projects; our estimated

[32] Within the DFBS, the use of derivatives to reduce milk price risk is limited.

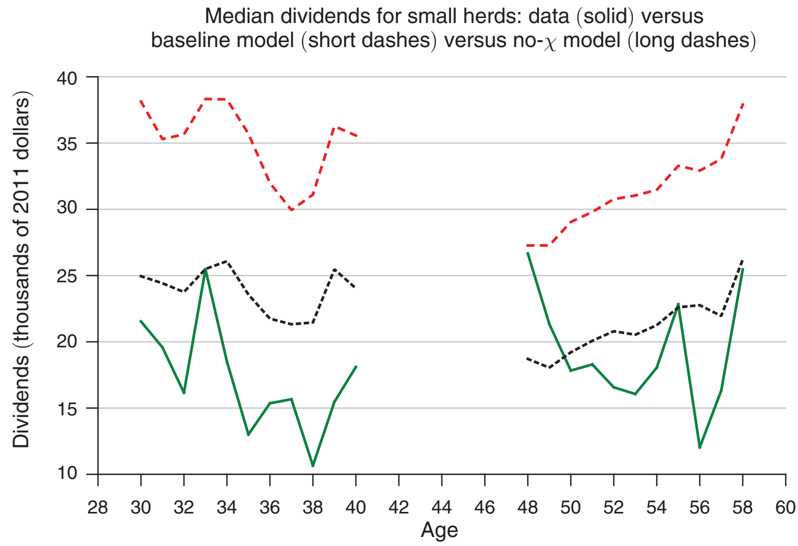

FIGURE 8. DIVIDENDS FOR SMALL HERDS, WITH AND WITHOUT NONPECUNIARY BENEFITS

discount rate is 2.7 percent. Our data do not reject Vereshchagina and Hopenhayn's proposed mechanisms, but they suggest an environment where the mechanisms are unlikely to arise. Our results are more in line with Caggese (2012), which finds that risk discourages entrepreneurial innovation. On the other hand, risk discourages investment and production only modestly. As the previous section shows, collateral and liquidity constraints have much larger effects.

D. *Joint Estimation*

Table 4 includes parameter estimates for alternate specifications of the model. In columns 2–4 we shut down individual mechanisms in turn (the nonpecuniary benefit, the collateral constraint, and risk aversion) and reestimate the model. The resulting estimates highlight the importance of estimating the mechanisms together. Consider column 2 of the table, which shows the estimated parameters for a version of the model without the nonpecuniary benefit ($\chi = 0$). Relative to the baseline, the most noteworthy change is an increase in the returns to management, α, for both stanchion and parlor operations. Increasing α allows the model to accommodate the existence of small, marginal farms, by replacing nonpecuniary benefits by pecuniary ones. This is illustrated in Figure 8, which compares dividend payouts for small herds in the baseline model and in the model with $\chi = 0$. Without nonpecuniary benefits, dividends are substantially and counterfactually larger: farming has become more profitable.

While we do not explicitly match dividend levels in our model (matching growth rates instead), a higher value of α degrades the model's fit along other dimensions. Even though the estimated value of ψ falls from 1.03 to 0.96, providing a greater capacity to borrow, the debt/asset ratio rises only slightly, from 0.506 to 0.515. This is because the reduction in estimated per-operator returns to scale, $1 - \alpha$, leads to a

Table 6—Results under Alternative Estimation Restrictions (Weighted by Herd Size)

	Fraction operating[a]	Capital	Debt/assets[b]	Investment/capital[b]	Dividend growth rate[c]	Optimal capital
(1) Baseline model	1.000	781	0.506	6.15	1.88	1,212
(2) $\chi = 0$	0.968	787	0.515	5.26	1.17	884
(3) $\psi = 0$	0.998	811	0.523	3.34	0.75	843
(4) $\nu = 0$	0.999	783	0.454	7.66	12.29	1,060

Notes:
[a] Relative to baseline case
[b] Ratios of averages
[c] Mean growth rates for annual averages

reduction in the optimal scale of operation. Comparing the first two rows of Table 6 shows that the optimal capital stock falls by over 27 percent. Investment also falls, albeit to a smaller extent, also worsening model fit. The SMD criterion increases by more than 30 percent.

Another consequence of removing the nonpecuniary benefit is to significantly reduce the importance of the borrowing constraint. Figure 7 shows the effects of relaxing the collateral constraint ψ to 0.5 for the baseline model (panel A) and for the model with $\chi = 0$ (panel B). In the absence of nonpecuniary benefits relaxing the collateral constraints leads to only a modest increase in the median capital stock of young, large-herd farms, and has almost no effect on any other group. In short, without the nonpecuniary benefit it is much harder to match the data on both the intensive and extensive margins, and the estimates that result imply a much smaller role for borrowing constraints.

Column 3 of Table 4 shows the effects of estimating a model with no collateral constraints, i.e., with $\psi = 0$. This specification also leads to higher estimates of α. In the baseline model removing the collateral constraints leads to counterfactually large capital stocks (see panel A of Figure 7). In the reestimated model, this tendency is moderated by reducing the desired capital stock through lower per-operator returns to scale. The estimated nonpecuniary benefit shrinks substantially, to accommodate the resulting increase in pecuniary benefits. The third row of Table 6 shows the effects of the revised specification on optimal capital levels and investment rates. Capital and indebtedness rise. Investment rates fall, as firms achieve their optimal capital stock more quickly.

Column 4 of Table 4 shows the effects of estimating a model with no risk aversion. With $\nu = 0$, farmers are willing to defer consumption in favor of investment. To restrain investment, the collateral constraint rises, from 1.03 to 1.08. Nonetheless, the behavior of this specification is very similar to the comparative statics results in Table 5. The fourth row of Table 6 shows that the dividend growth rate rises sharply, investment and capital increase, and debt falls.[33]

[33] One dimension along which the no-risk aversion specification out-performs the baseline specification is in generating high dividend volatility. This is because the baseline value of ν, which ensures low dividend growth, also dampens dividend volatility. As discussed in Section IVB our model probably overstates risk aversion. If this is indeed the case, our finding that the effects of reducing production risk are small may be conservative.

E. *Overview*

To sum up: our estimates and comparative statics exercises indicate that financial factors play an important role in farm outcomes both at the intensive and extensive margin. The collateral and liquidity constraints hinder capital investment, reduce output and assets, and sometimes drive farms out of business.[34] Liquidation costs impede the exit of low productivity farms, by reducing the wealth they can carry into their new occupation.

Our analysis also reveals that nonpecuniary benefits are a significant motivating force. They keep farms in operation, despite low and uncertain revenue flows, reinforcing the effects of the liquidation costs. When both mechanisms are in place, only a few highly unproductive farms choose to exit.

VI. The Farm Bill of 2014

The dairy provisions of the Farm Bill of 2014 replaced a largely defunct dairy price support program. Although the former program guaranteed a statutory price for milk, either through direct purchase or through the purchase of other dairy products,[35] the support price of $9.90 per hundred pounds (cwt.) of milk was widely considered inadequate. As the left panel of Figure 9 shows, by 2000 the national average milk price, to which the support price was indexed, was always substantially higher than $9.90 per cwt., while still volatile.

This situation, coupled with an increase in feed costs, provided the impetus for a policy change toward margin support, rather than price support. The milk margin is defined as the difference between the price of milk and the weighted average of the prices of corn, soybeans, and alfalfa. The program offers a baseline margin support of $4.00 per cwt. for all participants and higher support levels in exchange for a premium. The right panel of Figure 9 shows nominal milk margins, as calculated by Schnepf (2014), between January 2000 and September 2014. Margin supports in the range of $4 to $8 would have kicked in several times in our sample period.[36]

The close correlation between milk prices and the aggregate productivity shock, along with the assumption of constant input prices, imply that within our framework, the aggregate shock acts as a margin shock. We therefore model margin floors by eliminating the left-hand tail of the aggregate shock distribution. As Schnepf (2014) notes, the premium structure is intended to encourage farmers to choose a margin support level of $6.50 per cwt. This translates into truncating the aggregate shock distribution at the ninth percentile. The online Appendix provides more details on the margin support program, the calculation of the truncation level, and the computational mechanics of truncating the distribution.

[34] 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 or Mendoza 2010).

[35] Our description of the dairy provisions of the 2014 Farm Bill and its predecessors borrows heavily from the discussion in Schnepf (2014). We are grateful to Randy Schnepf for sharing his calculations of national average milk prices and milk margins.

[36] The 2018 Farm Bill continues the margin support program, with minor modifications to premia and thresholds for margin support.

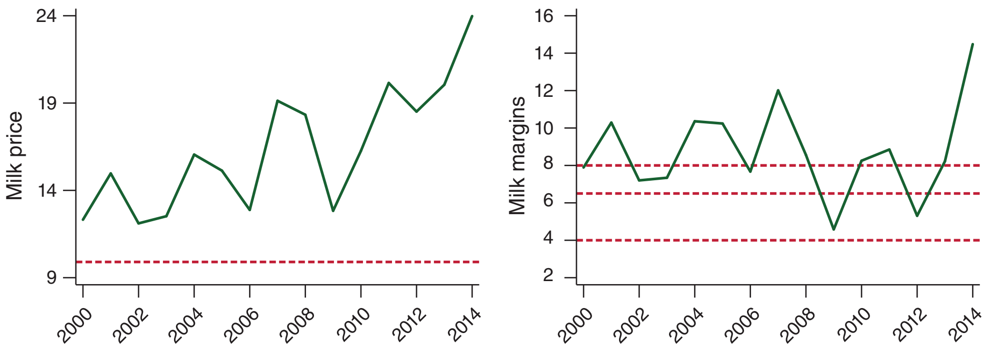

Figure 9. Milk Prices and Margins (Schnepf 2014)

Table 7 shows the effects of a margin support program of \$6.50. The first row of the table shows the no-farm bill benchmark.[37] The second row shows the effect of a \$6.50 margin support that is provided to farmers for free. The effects of the margin support are modest. The capital stock increases by about 1.5 percent and debt by 2.7 percent. The extensive margin, the number of farms operating, not reported in the table, is unchanged. Recalling row 14 of Table 5 shows that the effects of the margin support, which eliminates the worst downside risk, are similar to those of completely eliminating aggregate risk.

Row 3 of Table 7 shows the effects of coupling the margin support with the legislated premium (for large volumes) of \$0.29 per cwt. Even though this premium equals only about 1.6 percent of the average milk price, it significantly reduces the scale of operations. Under our specification, returns to scale per operator are given by $1 - \alpha$, with α estimated to be between 0.113 and 0.126 (see Table 4). This means that in the absence of frictions, the optimal scale of operations is quite sensitive to productivity, so that even a small fee can generate a significant contraction. The final column of Table 7 shows that the margin support premium reduces the optimal capital stock by nearly 13 percent. The actual capital stock falls by about 5.4 percent, however, as most farms are below their efficient size.

The small (or negative) effects of the Farm Bill on production may be consistent with large increases in the farmers' welfare, given how risk averse they are. To study welfare effects, we compute the additional equity each farm would need in the baseline model to achieve the lifetime utility that it would get in the model with margin supports. This supplement is then expressed as a fraction of the farm's initial equity.

Table 8 summarizes the welfare effects of the margin support program, first without and then with premia. The first row of Table 8 shows that receiving free margin supports is equivalent to a once and for all 3 percent increase in equity for the median farm, equivalent to about \$8,100. There is some variance in these benefits, with the largest being over 25 percent. Margin supports thus increase welfare, with the largest gains accruing to high-productivity farms, as shown by the positive

[37] Assessing the Farm Bill requires that we use a discretized shock process with many more grid points than in the baseline specification used to estimate the model (see the online Appendix). Using a finer shock grid significantly increases computation time, but its results are only marginally different from those of the baseline specification.

TABLE 7—OPERATIONAL EFFECTS OF THE 2014 FARM BILL (WEIGHTED BY HERD SIZE)

	Capital	Debt	Debt/assets	Cash/assets	Investment/capital (percent)	Optimal capital
Baseline model[a]	783	480	0.507	0.107	6.17	1,212
Margin support, no premium	795	493	0.512	0.108	6.22	1,212
Margin support, full premium	741	448	0.495	0.106	5.84	1,060

Notes: [a]Shock process revised to accommodate Farm Bill experiments. See the online Appendix.

TABLE 8—WELFARE EFFECTS OF THE 2014 FARM BILL (WEIGHTED BY HERD SIZE)

	Median	Mean	Minimum	Maximum	Correlation with μ
Margin support, no premium	2.98	3.44	0.37	25.51	0.72
Margin support, full premium	−12.31	−13.68	−41.89	−1.56	−0.75

Notes: Welfare measured as the increase in equity needed in the baseline model to achieve the welfare level found in each experiment. All numbers expressed as percentages of initial equity.

correlation in the last column. However, the negative effects of the premium on production are matched by negative effects on welfare. The net effect of the Farm Bill with a premium is equivalent to a 12.3 percent fall in equity for the median farm. The average fall is about 14 percent, similar in magnitude to the 13 percent fall in optimal capital, whereas the largest losses are as much as 42 percent of initial equity. High-productivity farms face the largest losses.

In short, we find that the negative effects of the margin support premium outweigh the small positive effects of the support itself. It is possible that our model, which is calibrated to an annual frequency, understates the effects of the margin support program, which operates at a two-month frequency. Schnepf (2014) shows that milk margins change significantly from month to month. Moreover, the cash holdings observed in the DFBS, recorded at the beginnings and ends of calendar years, may understate farms' actual liquidity needs, which tend to be highest in the summer.[38] The combination of seasonal cash shortages and monthly margin fluctuations may enhance the impact of margin support. Finally, the distribution of aggregate shocks is based on data from our sample period of 2001–2011. As Figure 9 shows, milk margins fell below the floor in 2012. If the risk of low margins is greater than that found in our sample, margin supports will be more valuable than our estimates suggest. On the other hand, Johnson (2017) reports widespread dissatisfaction with the program, and an uptake rate of only 54 percent. Within that group, 77 percent acquired only the free \$4.00 coverage.

VII. Sensitivity Analyses

As we discussed above, nonpecuniary benefits (χ) and liquidation costs (λ) both discourage the exit of low-productivity farms, and are thus difficult to identify simultaneously. We also argued that the nonpecuniary benefit is positively related to

[38] Conversation with Wayne Knoblauch, April 20, 2015.

Table 9—Robustness Exercises (Weighted by Herd Size)

	Fraction operating[a]	Capital	Debt/assets[b]	Investment/capital (percent)[b]	Dividend growth rate (percent)[c]	Optimal capital
1. Baseline model	1.000	781	0.506	6.15	1.88	1,212
2. $\lambda = 0.175$	1.001	779	0.506	6.16	1.87	1,212
3. $w = \$30\text{K}$	1.000	781	0.506	6.17	1.93	1,212
4. No renegotiation	0.961	820	0.500	6.39	1.54	1,211

Notes:
[a]Relative to baseline case
[b]Ratios of averages
[c]Mean growth rates for annual averages

the outside wage w: a low-productivity farm facing a high outside wage will remain in operation only if the nonpecuniary benefit to farming is also high. In this section we formally explore the sensitivity of our results to alternative values of λ and w, by changing these parameters and reestimating the model. We also estimate a version of the model with no renegotiation. The parameter estimates for these alternative specifications can be found in columns 5–7 of Table 4. Table 9 compares predictions of a few key variables. In the online Appendix we discuss the effects of using herd size weights in our estimation procedure.

A. *Liquidation Costs*

Our benchmark estimate of λ, a loss rate of 0.35, is somewhat higher than those reported in the finance literature (see, e.g., Andrade and Kaplan 1998; or Hennessy and Whited 2007). When λ is cut in half, to 0.175, the estimated value of the nonpecuniary benefit χ_C increases by about 15 percent, from \$6,300 to \$7,260, so that the model continues to match the participation observed in the data. The other parameters of the model are essentially unaffected, and row 2 of Table 9 shows that the model-predicted moments are unaffected as well.

B. *Value of the Outside Wage*

Doubling the outside wage w to \$30,000 (while leaving liquidation costs at their baseline value) also increases the estimated nonpecuniary benefit, by \$15,600, roughly the increase in w. As in the previous exercise, higher nonpecuniary benefits are needed to match the extensive margin, but the other parameters are unaffected.

These results suggest that nonpecuniary benefits are important to explaining the dynamics we observe in the data. While we would expect the value of these benefits to vary across industries, as a result of heterogeneous liquidation costs or outside options, our estimation shows that it is hard to deny their existence.

C. *Debt Renegotiation*

In our baseline specification indebted farms can renegotiate their loans. This is consistent with the DFBS, where farms with negative net worth sometimes continue to operate. The bottom row of Table 9 shows results from a specification with no renegotiation, where farms with negative net worth must liquidate. The effects of this change are modest. The fraction of farms operating is only 3.9 percent smaller, and most other variables are similarly close to their baseline values. The most notable difference is that the optimal capital stock is slightly *smaller*, implying that the exiting farms are not from the bottom of the productivity distribution. Renegotiation thus plays a role in keeping productive farms alive. In most other respects, however, its effects are minor. The last column of Table 4 shows that the estimated value of the nonpecuniary benefit is higher in a model with no renegotiation. When farms with negative net worth are forced to exit, the model overstates exit rates. A higher nonpecuniary benefit encourages more farms to stay in business.

VIII. Conclusions

Although a wide range of policy measures are aimed at promoting entrepreneurial activity, there is still considerable debate about the forces that drive it. In this paper we use a dynamic model to assess how financial constraints, nonpecuniary benefits, and risk jointly affect entrepreneurs. We build a life-cycle model that incorporates all three considerations, to our knowledge the first of its kind, and estimate it with a rich panel of owner-operated dairy farms in New York State. Using a simulated minimum distance estimator, we fit the model to real variables such as input use, capital, and revenues, and to financial variables such as debt, dividends, and cash holdings. Matching both production and financial variables allows us to disentangle the effects of real and financial factors.

Our principal finding is that the effects of financial constraints and nonpecuniary benefits are of first-order importance, but those of uninsured production risk are not. Collateral constraints on investment and liquidity constraints on the purchase of intermediate goods restrict, sometimes significantly, capital holdings, input purchases, and output. Nonpecuniary benefits and liquidation costs discourage low-productivity operators from exiting the industry. In contrast, eliminating aggregate production risk has very modest effects on farm decisions. Our model predicts that the insurance provided by the milk margin support program of the 2014 Farm Bill also provides limited benefits, which is confirmed by its limited uptake by dairy farmers.

We find that much of the variation in farm productivity can be attributed to permanent idiosyncratic differences. While high-productivity farms grew steadily over the sample period and appear to have been facing financial constraints, low-productivity farms appear to have been close to their optimal size throughout. This suggests that rather than maximizing the number of entrepreneurs, many of whom operate for nonpecuniary reasons, entrepreneurial policy may work better by helping the most promising entrepreneurs expand.

One reason our results are valuable is that detailed joint real and financial data for small firms are rarely available. But even though our data are especially well suited to our approach, the firms that generate them are similar to many other US firms. We thus expect that our methodology and findings can be extended to a variety of settings.

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