Journal of Development Economics 97 (2012) 201–220

Contents lists available at ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/devec

Financial constraints and occupational choice in Thai villages ☆

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ARTICLE INFO

Article history:
Received 21 November 2006
Received in revised form 17 November 2010
Accepted 16 May 2011

JEL classification:
O12
C52
D82

Keywords:
Occupational choice
Financial constraints
Maximum likelihood

ABSTRACT

Financial constraints and entrepreneurship are key factors affecting economic performance in developing countries. I formulate and solve a model of occupational choice with moral hazard under three alternative financial market environments: savings only, borrowing and lending with default and moral hazard constrained insurance. I use computationally efficient techniques based on mechanism design, genetic algorithms and maximum likelihood to estimate and statistically test these models of financial constraints. Using occupational choice data from Thai villages I find evidence that the saving only regime is rejected in favor of regimes allowing for borrowing and/or insurance, especially in higher-wealth data stratifications. A direct test between the borrowing and insurance regimes reveals that neither can be rejected in favor of the other. Allowing ex-ante lotteries over wealth improves the explanatory power of the model. I also find evidence for differences in the best fitting regimes by region, wealth, and access to formal credit.

1. Introduction

Entrepreneurship has been widely recognized as one of the engines of economic growth and development.[1] Entrepreneurial activity involves investment in capital which comes from two basic sources: own wealth or borrowed funds. The ability to borrow depends on how well financial markets function as shaped by information or enforcement constraints. As a result, the relationship between entrepreneurship and wealth is bidirectional: the distribution of current wealth and the financial environment are crucial determinants of occupational choice, which in turn determines the future distribution of wealth.

I this paper I use data on pre-existing wealth and occupational choice in Thai villages to empirically evaluate three theoretical models of entrepreneurship under financial constraints – saving only, borrowing with default and information-constrained insurance.[2] Because starting a business requires capital, the existence of financial constraints implies a positive relationship between entrepreneurship and pre-existing wealth which is stronger the more imperfect financial markets are. This paper's main objective is to uncover the source of market imperfections shaping occupational choices by identifying the relevant theoretical models to use in future work (viewed as bases for reduced-form empirical analysis or as potential policy tools) and by identifying which models are rejected by the data and can be set aside. The computational and estimation methodology developed here can be readily used by other researchers with other data sets or with alternative models of financial constraints. Specifically, I use structural estimation and testing methods to determine which financial market setting produces a mapping between initial wealth and ex-post occupational choice closest to that observed in Thailand. The results of this empirical investigation bear relevance to several publicized policy fronts: assisting small business enterprises as an engine of development, identifying potential roles for microcredit or similar programs to remedy salient deficiencies in rural financial markets, designing social safety nets to overcome problems caused by missing or imperfect insurance markets, etc.

The theoretical setting is an occupational choice model with financial constraints due to moral hazard and limited liability. There is a continuum of risk averse agents heterogeneous in their wealth endowments and entrepreneurial ability. The agents can choose between two possible occupations: 'entrepreneurship', using labor effort and capital investment as inputs in production, or 'subsistence', using labor only. Output is stochastic. The agents can also enter into contracts with a competitive financial intermediary. These contracts are subject to a moral hazard problem as the effort supplied by entrepreneurs is unobservable to outsiders. Combined with the limited liability assumption that agents can repay an investment loan only when their project is successful, this implies that poor, highly leveraged borrowers' incentives to supply high effort are low and hence they

☆ Comments from F. Buera, L. Calvet, P-A. Chiappori, P. Dubois, R. Myerson, P. Reny, M. Rosenzweig, two anonymous referees and participants in the Theory and development seminar at the University of Chicago, the NEUDC and CEF conferences are gratefully acknowledged. I am much indebted to Robert Townsend for extensive discussions and for his Thailand survey data. I also thank the Social Sciences and Humanities Research Council of Canada for financial support.

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[1] Knight (1921) and Schumpeter (1934) among many others.

[2] Earlier empirical work by Paulson and Townsend (2004) demonstrates that financial constraints have an important effect on entrepreneurship in Thailand.

0304-3878/$ – see front matter
doi:10.1016/j.jdeveco.2011.05.002

would be subject to high interest rates or rationed out of the credit market even if their productivity is high. This results in suboptimal effort and investment.

When studying financial market imperfections most authors assume a single, specific financial environment (e.g., no access to credit, trade in a single risk-free asset, etc.). In contrast, keeping preferences and technology the same, I study three alternative financial market environments (regimes): a "savings only" regime precluding any borrowing, a "borrowing and lending" regime with the possibility of default but no other contingencies, and a "constrained insurance" regime allowing any contingent transfers to and from the financial intermediary subject to incentive compatibility. The first regime features exogenously incomplete markets – the admissible financial contract takes a specific form (deposit contract with fixed interest). In contrast, the optimal contracts in the borrowing and insurance regimes are endogenously constrained by the default and moral hazard problems. The theoretical regimes I study here resemble the basic types of financial institutions and credit sources observed in the data and the contracts they offer. Formal saving and credit contracts offered by commercial or government banks and credit unions map into the saving and/or borrowing regimes while more informal contracts, especially loans by friends and relatives, are often more contingency-based like the constrained insurance regime.

The indivisibility inherent in the discrete occupational choice creates a non-convexity in the agent's indirect utility of wealth. This means that randomization can be efficiency improving. That is why, within each of the three basic financial settings, I also consider the effect of augmenting the financial contract with ex-ante lotteries over wealth, which I prove are sufficient to convexify the problem. The resulting six financial regimes differ significantly in the financial constraints they impose creating a spectrum ranging from the very restrictive savings only contract which precludes any borrowing to the constrained-optimal insurance contract with lotteries.

The model predictions for the relationship between pre-existing wealth and ex-post occupational status differ substantially across the financial regimes, especially at low wealth levels. This provides the basis for my empirical strategy. I use data from a socioeconomic survey fielded in Thai villages in 1997 that includes business and non-business households from two distinct regions of the country — the rural and semi-urban households living in the central region close to the capital Bangkok and the traditionally rural households living in the North-East. The data contain information on household wealth, occupational status (including entrepreneurial activities) and binary variables for access to formal or informal financial institutions (commercial banks, money lenders, friends and relatives).

To address potential endogeneity, in the empirical analysis I use wealth six years *prior to* the survey and restrict attention only to businesses started afterwards, i.e., within the five years before the survey (see the Empirical analysis section for more details). Various robustness checks are also performed, including a run with simulated data. Admittedly, to answer more completely the endogeneity problem, one would ideally like to use panel data on wealth and entry and exit from entrepreneurship together with a dynamic model of occupational choice under financial constraints. Given my data and computational constraints, this paper provides the first step towards this goal, focusing on studying the one-time transition from traditional farm work into entrepreneurship as a major building block of the bidirectional dynamics of wealth accumulation and occupational choice.

The Thai data is used to evaluate and compare empirically the constrained financial market environments described above. I estimate the model under each financial regime using maximum likelihood and genetic algorithms. I then use Vuong's (1989) model comparison test to establish whether one can reject one financial regime in favor of the others relative to the data. This can be viewed as a 'horse race' between competing structural models, allowing the data to sort out the 'winners' and the 'losers'.[3] The likelihood function for each regime is constructed by matching the expected probability of becoming entrepreneur generated by the model at each initial wealth level in the sample with the corresponding household occupational status taken from the data.

The regime comparison results show that the Thai wealth and occupational choice data allow me to distinguish among the competing models of incomplete financial markets and evaluate the role of randomization. I find that the savings only regime is rejected in favor of both the borrowing and lending and insurance regimes, especially in data stratifications characterized with higher average wealth and/or higher number of businesses. This can be interpreted as evidence for more advanced financial contracts with elements of credit and/or contingent transfers operating in these locations. The more restrictive borrowing contract which does not allow contingencies aside from default is statistically indistinguishable from the (constrained optimal) insurance regime using the Vuong test. The possibility of convexifying randomization is supported by the estimation results: the specifications with lotteries provide better fit compared to those without.

To estimate the model I first solve for the optimal financial contracts in each regime which determine the agents' occupational choices as function of initial wealth. Given that my ultimate goal is taking the regimes to the data, I adopt a numerical approach. The technical contribution of the paper is that it provides a flexible methodology to solve, estimate and test among structural models of incomplete markets using advanced numerical techniques. Alternative regimes or functional forms can be easily added. Further on the technical side, an important theoretical result is demonstrating the equivalence of allocation lotteries over consumption, investment, effort, and output which arise in the insurance regime to a simple ex-ante lottery over wealth followed by deterministic contracts for each occupation. This equivalence allows separating the hard mechanism design problem of solving for the optimal constrained insurance contract into two stages solvable by standard methods. This yields substantial improvements in computational speed and accuracy.

This paper is closely related to Paulson et al. (2006), where we also analyze sources of financial constraints for rural households in Thailand. We allow for limited liability due to an enforcement problem as in Evans and Jovanovic (1989), moral hazard as in Aghion and Bolton (1997) and a combination of both constraints. We find structural and reduced form evidence that the dominant source of credit market imperfections is moral hazard. The hypothesis that limited liability alone can explain the data is rejected. In contrast, the current paper takes the moral hazard setting as given and compares exogenously vs. endogenously incomplete market environments featuring financial contracts similar to those observed in practice. Unlike Paulson et al. (2006), I find evidence of differences in the best matching financial regime across data stratifications by region and wealth. In addition, the empirical evaluation of wealth lotteries in an occupational choice model is not present in previous work Jappelli and Pistaferri (2006).

More generally, this research relates to several branches of the existing literature. On the theory side, models of occupational choice have stressed the importance of asymmetric information or exogenous borrowing constraints (Aghion and Bolton, 1997; Banerjee and Newman, 1993; Lloyd-Ellis and Bernhardt, 2000; Piketty, 1997). At the same time, the empirical literature has argued that financial constraints are among the key factors affecting economic performance in developing countries. The presence of financial market imperfections implies that the ability to borrow and hence the probability of starting

[3] The regime evaluation is similar in spirit to Lehnert et al. (1999) who use simulated data to compare models of liquidity constraints or Jappelli and Pistaferri (2006) who test across three models of intertemporal consumption choice. Ligon (1998) uses GMM to test consumption Euler equation implications of moral hazard constrained insurance vs. a Bewley-type model of exogenously incomplete markets. See also Fafchamps (1993) and Wolak (1994) for applications of the Vuong test in development and industrial organization.

business depends on one's own wealth (Dunn and Holtz-Eakin, 2000; Evans and Jovanovic, 1989; Holtz-Eakin et al., 1994). The paper also relates to the empirical literature on risk sharing in development economies (Jakoby and Skoufias, 1998; Ligon et al., 2002; Townsend, 1994; Udry, 1994). Most formal tests of risk sharing reject the full insurance hypothesis. To find the reason for the rejection, it is important to identify the sources of financial constraints and uncover the theoretical models describing the data best.

2. Model

2.1. Basics

There is a continuum of agents, $i \in I$ heterogeneous in their endowments (hereafter 'wealth'), $a_i \geq 0$, and entrepreneurial ability, $\theta_i \geq 0$, and who have preferences represented by $u(c, z)$ where c is consumption and z is labor effort. The utility function, u is concave, strictly increasing in the first and strictly decreasing in the second argument. There are two available technologies through which a single consumption and investment good is produced. The choice between the technologies is interpreted as choice between occupations. The first technology involves investing a positive amount of wealth, k, and is summarized by $p^E(q|k, z)$, representing the probability of achieving output level q given effort z and investment k. The agents who use this technology will be called 'entrepreneurs'. Note that since investment can vary continuously, the relationship between wealth and occupational choice is not driven by technological indivisibilities. The second technology is operated without making any investment and is represented by $p^W(q|z)$ — the probability of achieving output q given effort z and no investment. The agents using this technology will be called 'workers'. This technology is interpreted as a subsistence (agricultural) technology.

For simplicity, assume that there are two possible output realizations for each occupation. For the entrepreneurs, output can take two values: $q = \theta q_h$ and $q = \theta q_l$, with $q_h > q_l$, whereas for the workers output is either w_h or w_l, with $w_h > w_l$. Note that higher entrepreneurial ability leads to higher output. That is, for the same levels of investment and effort a more able entrepreneur would achieve higher expected output. I further set $q_l = w_l = 0$ which is henceforth interpreted as failure of the business project or agricultural crop. Entrepreneurial ability θ is continuously distributed with pdf $\eta(\theta)$.

There exists a risk-neutral competitive financial intermediary ("bank") with whom agents can sign one-period financial contracts involving saving, borrowing or insurance. The effort supplied by entrepreneurs is unobservable by the bank, which results in a moral hazard problem. It is assumed, however, that the bank can observe agents' wealth, output, investment, and ability thus disregarding adverse selection or costly state verification problems.[4] Worker's effort is assumed to be observable and contractible.[5] Given their wealth, ability, and feasible financial contracts with the bank, the agents choose the occupation which provides them with higher expected utility.

The timing is as follows. All agents live two periods starting with their initial wealth endowment. In the first period they decide on their occupation, sign a financial contract with the intermediary, invest, and exert effort. In the second period output is realized, the agents execute the terms of their financial contract (e.g., return a loan or withdraw their savings), the agents consume and die.

[4] The current model can be extended to account for adverse selection or hidden output by adding the relevant truth-telling constraints to the optimization problems. For example, Abbring et al. (2002) discuss empirical strategies to jointly test and distinguish moral hazard from adverse selection.

[5] This assumption is not crucial for the results A possible interpretation could be that the subsistence technology involves simple and easier to control tasks.

2.2. Financial environments

I study three incomplete markets financial environments (regimes) — saving only, borrowing and lending with default and constrained insurance. The feasible set of contracts in each regime is imposed exogenously, i.e., agents cannot choose which regime to be in but, within the constraints of each regime, contracts are chosen optimally.[6] Further, the financial contracts I analyze are not arbitrary but were chosen to match the observed institutional environment in the data.

2.2.1. Savings only

The first environment allows only saving (storage) contracts, i.e., no borrowing is possible. Agents can only deposit an amount with the intermediary earning riskless gross return of r. The maximization problem of an entrepreneur with initial wealth a and ability θ is:

$$\max_{z,k} p^e(z,k)u(c_h,z) + (1-p^e(z,k))u(c_l,z) \tag{1}$$
$$\text{s.t. } c_h = \theta q_h + r(a-k)$$
$$c_l = r(a-k)$$
$$0 \leq k \leq a$$

where c_h and c_l are the levels of consumption respectively for success and failure and where $p^e(z, k) \equiv p^E(q = \theta q_h|z, k)$ is the probability of success. Consumption in each state is simply the realized output plus any return on savings. The inequality constraint states that no borrowing is possible and hence all investment must be self-financed. There is no moral hazard problem in this financial regime as the intermediary is not involved financially in the agent's project. Clearly, the saving only contract is inefficient since some sufficiently poor but high-ability agents do not become entrepreneurs.[7]

Similarly, a worker with initial wealth a solves:

$$\max_{z} \; p^w(z)u(c_h,z) + (1-p^w(z))u(c_l,z)$$
$$\text{s.t. } c_h = w_h + ra \tag{2}$$
$$c_l = ra$$

where $p^w(z) = p^W(q = w_h|z)$. Since there is no investment all initial wealth is deposited with the bank.

2.2.2. Borrowing and lending with default

In this financial environment the feasible contracts are standard borrowing/lending arrangements between the agents and the bank: an agent (a, θ) either deposits some amount as in the savings only regime above and earns r, or she can request a loan from the intermediary. In the latter case, the bank announces a repayment rate, $R(a, \theta)$. The agent takes the repayment schedule $R(a, \theta)$ as given and optimally decides how much to borrow, including the option not to borrow but save. I assume limited liability in the sense that consumption must be non-negative in each state and no harsher penalties can be imposed.[8] This means that in case of project failure (zero output), a borrowing agent declares default and is unable to repay anything. The bank takes this possibility into account by setting the required repayment under failure to zero and adjusts the repayment due under success by setting the effective loan interest rate such as to break even. Formally, given gross

[6] This is done for simplicity but may be justified by transaction costs, lack of appropriate institutional mechanisms, etc. Such a justification, however, remains outside the scope of this paper.

[7] Everywhere it is assumed that the support of θ and q_h and w_h are such that high-ability agents are entrepreneurs in the first best (the entrepreneurial technology is sufficiently productive relative to subsistence). The other case is trivial and omitted.

[8] The same form of limited liability is also assumed in the saving only and constrained insurance regimes as well as for savers in the borrowing regime; however in those cases it generally does not bind at optimum (as long as $a > k$ and u is strictly concave).

borrowing interest rate under success $R(a, \theta)$, the maximization problem of a borrowing entrepreneur is:

$$\begin{aligned} &\max_{k,z} \; p^e(z,k)u(c_h,z) + (1-p^e(z,k))u(c_l,z) \\ &\text{s.t.}\, c_h = \theta q_h - R(a,\theta)(k-a) \\ &\quad c_l = 0 \end{aligned} \tag{3}$$

Remember that effort is unobservable to the bank so any desired level must be induced by setting the interest rate $R(a, \theta)$ accordingly. Zero profits (free entry) in the competitive financial sector implies that the bank must earn its reservation return (assumed equal to r) on each loan. That is, $R(a, \theta)$ must solve

$$R(a,\theta) = \frac{r}{p^e\left(\hat{z}(R(a,\theta)), \hat{k}(R(a,\theta))\right)}, \tag{4}$$

where $\hat{z}(R(a,\theta))$ and $\hat{k}(R(a,\theta))$ are the solutions of Eq. (3) taking $R(a,\theta)$ as given.[9] The interest rate is endogenously determined and varies with wealth and ability. The interpretation of condition (Eq. (4)) is that, to offset the zero return it makes under failure, the bank has to charge interest rate higher than the riskless rate, r in case of success, which happens with probability less than one.

The limited liability assumption introduces an asymmetry between the optimization problems of borrowers and lenders. In contrast to problem (Eq. (3)), a lending (saving) entrepreneur solves problem (Eq. (1)) without the constraint $k \leq a$.The workers solve exactly the same problem as before, Eq. (2), since they do not invest and do not need to borrow. Compared to the savings only contract the borrowing and lending regime provides an opportunity for agents with low a but high ability to borrow and become entrepreneurs. On the other hand, the possibility of default is an extra consumption risk that borrowers take. As such, the borrowing and lending contract is suboptimal in this moral hazard environment populated by risk averse agents as it provides no insurance in case of project failure. It weakly dominates the saving only contract though, since the agent can always choose not to borrow.

2.2.3. Constrained insurance

The third financial environment I study allows state-contingent transfers between the agent and the intermediary. That is, the contracts it permits can be viewed as partial insurance cum credit contracts. It is well known that under full information, risk-averse agent and risk neutral intermediary the optimal contract must provide equal consumption to the agent in all states of the world. This is achieved by the agent making a net transfer to the intermediary in case of success and the intermediary making a net transfer to the agent in case of failure. The contracts between the workers and the bank have this property. However, since entrepreneurial effort is unobservable, full consumption smoothing is not possible as it is not incentive compatible (Hart and Holmstrom, 1987). Indeed, if the agent were promised the same consumption under success and failure, she would always choose the lowest possible effort level (zero) since effort is costly, and output will be zero. Thus, the incentive-constrained optimal contract for the entrepreneurs has the bank providing partial insurance — the agent's consumption varies with output (but less than in the saving only or borrowing contracts). The constrained insurance contract Pareto dominates the borrowing and lending and saving only contracts since it provides partial consumption smoothing and also allows poor high-ability agents to borrow.

I use a mechanism design approach to formulate and solve a principal-agent problem for the constrained-optimal contract and the agents' underlying occupational choice. Namely, the bank sets an investment level, k, output contingent consumption, $c_h(q)$ and $c_l(q)$, and recommends an (incentive-compatible) effort level, z. Thus, a *contract* between the bank and the agent is defined as the triplet $(c(q), z, k)$. If it is optimal to set $k>0$, the agent is an entrepreneur, while if the bank optimally sets $k=0$, the agent is assigned to be a worker.

Because of the free entry assumption, the bank's profits are zero in equilibrium. Thus, we can think of the bank as maximizing the expected utility of its customers as function of their wealth and ability, subject to breaking even and incentive compatibility. Or, think of it as setting the bank's profits to zero and finding the maximum feasible utility for the agent which corresponds to the point on the Pareto frontier where the agent has all the bargaining power and the bank/principal is at her reservation payoff.

There are two potential sources of non-convexity in the constrained insurance contracting problem. First, because of the occupational choice indivisibility, the agent's indirect utility function may not be globally concave (see more on this below). Second, it is well known that the non-linear incentive compatibility constraints can also make the problem non-convex (e.g., Rogerson, 1985). The presence of these non-convexities in the contracting problem has two crucial implications. First, in general one cannot simply solve the problem using standard first-order conditions techniques as in the savings only or borrowing environments. Second, the non-convexity implies that the optimal constrained insurance contract might feature randomization (lotteries) over investment, effort or consumption.

An extremely general method for numerically solving such non-convex principal–agent problems is to discretize the variables c, z, k and q and re-write the problem in terms of new variables, $\pi(c, q, z, k|a, \theta)$ corresponding to the probabilities that particular consumption, c, effort, z and investment, k is assigned as a function of agent's wealth, a, and ability, θ given output, q (Phelan and Townsend, 1991; Prescott and Townsend, 1984). This can be interpreted as the principal offering randomization or lotteries over consumption, output, investment, and effort allocations to the agent. I will call these "allocation lotteries". Alternatively, think of the principal facing a continuum of agents of each type (a, θ) and assigning different fractions of them to different allocations (c, q, z, k). The usefulness of this approach is that the originally non-convex problem becomes a linear program (convex by definition) in the variables $\pi(c, q, z, k|a, \theta)$ (see the references above for full details).

Formally, I write the bank's maximization problem for an agent with wealth a and ability θ as the following linear program in the variables $\pi(c, q, z, k|a, \theta)$,

$$\max_{\pi(c,q,z,k|a,\theta)\geq 0} \sum_{c,q,z,k} \pi(c,q,z,k|a,\theta)u(c,z) \tag{5}$$

subject to

$$\sum_c \pi\left(c,\bar{q},\bar{z},\bar{k}|a,\theta\right) = p\left(\bar{q}|\bar{z},\bar{k}\right)\sum_{c,q}\pi\left(c,q,\bar{z},\bar{k}|a,\theta\right) \quad \text{for all } \bar{q},\bar{z},\bar{k} \tag{6}$$

$$\sum_{c,q,z,k} \pi(c,q,z,k|a,\theta)(c-q) = r\sum_{c,q,z,k}\pi(c,q,z,k|a,\theta)(a-k) \tag{7}$$

$$\begin{aligned} &\sum_{c,q} \pi(c,q,z,k|a,\theta)u(c,z) \\ &\quad \geq \sum_{c,q}\pi(c,q,z,k|a,\theta)\frac{p(q|z',k)}{p(q|z,k)}u(c,z') \text{ for all } k>0,\ z,\ z'\neq z \end{aligned} \tag{8}$$

$$\sum_{c,q,z,k} \pi(c,q,z,k|a,\theta) = 1 \tag{9}$$

[9] Note that $\hat{z}(R)$ and $\hat{k}(R)$ implicitly incorporate the incentive compatibility constraint on the interest rate schedule $R(a, \theta)$.

and where

$$p(q|z,k) = \begin{cases} p^E(q|z,k) & \text{if } k > 0 \\ p^W(q|z) & \text{if } k = 0 \end{cases}. \tag{10}$$

The objective function is the expected utility that the agent obtains at the allocations (c, q, z, k).Constraint (Eq. (6)) ensures that the probabilities constituting the optimal contract, $\pi(c, q, z, k)$ are Bayes-rule consistent with the production technology $p(q|z, k)$. The second constraint, Eq. (7), is the zero-profit condition, stating that, on average, all outgoing transfers from the bank must balance all incoming transfers. Constraint (Eq. (8)) is the incentive compatibility constraint which ensures that the equilibrium effort level will be implemented by the agent. It states that the expected utility of implementing the recommended level of z (the left hand side) must be larger or equal to the expected utility of deviating to any alternative effort level z'. Finally, Eq. (9) requires that the allocation probabilities add up to one.

2.3. Solving for the optimal financial contracts

The optimization problems for each occupation in the savings only and borrowing regimes are solved numerically via non-linear techniques based on the quadratic programming approach. The relative simplicity of the problems allows substituting the constraints into the objective which transforms them into relatively standard unconstrained optimization problems and/or systems of non-linear equations.

In this subsection and Appendix B I develop a computationally efficient algorithm for solving for the optimal contract in the constrained insurance regime. Although the linear programming (LP) approach is very general and does not rely on almost any assumptions on the functional forms used, it has some serious drawbacks. First, even with very modest grid sizes, e.g., 20 points each for c, k, z, the dimension of the problem is quite high (16,000 variables and 15,602 constraints). This 'dimensionality curse' requires a lot of computer memory and time, especially if denser grids are needed. On the other hand, if too coarse grids are used the accuracy of the solution deteriorates. Further, discretizing the problem can introduce 'grid-lotteries'which arise when the true solution is between two grid points. These lotteries have no economic function and contaminate the solution with numerical error.

Here, I utilize the economic structure of the occupational choice model to propose an alternative solution method which combines the generality of the LP approach with the speed of non-linear methods.[10] The main result I use is proving that, under mild assumptions, the solution to the linear program (Eqs. (5)–(9)) which allows for any possible allocation randomizations is equivalent to the solution of a much simpler problem in which ex-ante wealth lotteries are the only randomization device.

Proposition 1. (Equivalence between allocation lotteries and wealth lotteries)

Assume the utility function is separable in effort and consumption, strictly concave in consumption and strictly convex in effort. Then the optimal effort, investment, and consumption levels solving program, (Eqs. (5)–(9)) (the 'allocation lottery problem') coincide with the solutions of the following problems,

$$\max_{k,z,c_h,c_l} \; u^* \equiv p^e(z,k)u(c_h,z) + (1-p^e(z,k))u(c_l,z) \tag{11}$$

$$s.t. \;\; z \in \arg\max_z \; u^* \quad \text{given } \; k, c_l, c_h \;\; \text{ICC} \tag{12}$$

$$p^e(z,k)c_h + (1-p^e(z,k))c_l = r(a-k) + p^e(z,k)\theta q_h \;\; \text{BE1} \tag{13}$$

and

$$\max_{z,c} \; u(c,z) \tag{14}$$

$$s.t. \; c = p^w(z)w_h + ra, \;\; BE2 \tag{15}$$

combined with an ex-ante lottery over wealth only (the 'wealth lottery problem').

Proof. See Appendix A

The equivalence between the allocation lottery and the wealth lottery problems is the basis of the algorithm I use to compute the optimal constrained insurance contract. The usefulness of this step is to reduce the dimensionality of the original problem by showing it is equivalent to the two-stage procedure of (i) solving the optimization problem for each occupation separately and (ii) computing the optimal wealth lottery. Appendix B contains the details.

Proposition 1 implies that under mild assumptions the function of the completely general randomization via allocation lotteries in the moral-hazard constrained contracting problem Eqs. (5)-(9) is to allow agents to engage in implicit lotteries over wealth. It is optimal for the agents to engage in such randomization as their indirect utility of wealth has convex parts induced by the indivisibility of occupational choice. I expand on this next.

2.4. Wealth lotteries and randomization

From the maximization problems of entrepreneurs and workers, we can derive their indirect utility functions, $v^E(a, \theta)$ and $v^W(a)$ in each of the financial regimes. For the moment, assume that ability is fixed and interpret v^E as function of wealth only. By standard arguments, since u is concave, v^E and v^W are locally concave in a almost everywhere.[11] Given her wealth, a, each agent chooses the occupation that provides her with higher indirect utility. Thus, the utility realization she obtains, $v(a)$ lies on the upper envelope of $v^E(a)$ and $v^W(a)$, i.e., $v(a) \equiv max\{v^E(a), v^W(a)\}$.Even though v^E and v^W are concave in wealth, $v(a)$ is not concave in general. The reason is the indivisibility in the occupational choice problem — agents are able to hold only one occupation at a time.

Fig. 1 illustrates the non-concavity of the agent's value function $v(a)$.[12] It also shows how randomization over wealth can be welfare improving in ex-ante expected utility sense over the wealth range (a_1, a_2). An agent with wealth $\hat{a} \in (a_1, a_2)$ where v is convex is better off by taking a lottery that with probability, $\mu = \frac{\hat{a}-a_1}{a_2-a_1}$ gives him the wealth level, $a_2 > \hat{a}$ (point B) and, with the residual probability, $1-\mu$ gives him wealth $a_1 < \hat{a}$ (point A), since $\mu v(a_1) + (1-\mu)v(a_2) > v(\hat{a})$. Alternatively, one can think of having many individuals at wealth $\hat{a}$ for which $v(a)$ is convex, pool their wealths after which an appropriate fraction of them is assigned randomly wealth higher than $\hat{a}$ while the rest is assigned wealth lower than $\hat{a}$ such that the total pooled wealth is exhausted.

Using such ex-ante randomization or lotteries is not new or rare in economic modeling. For example, Hansen (1985) builds a macroeconomic model with indivisible labor and introduces lotteries over employment status to convexify the consumption set; Lehnert (1998) augments a standard growth model with financial constraints with a richer contract space allowing randomization and shows that this raises welfare; Rosen (2002) discusses how occupational lotteries can be welfare-improving and 'manufacture' inequality in settings with indivisibility; etc. Allowing randomization over wealth can also be interpreted as proxy for allowing financial markets to convexify the utility possibility frontier, as in allowing a richer asset structure. By

[10] Full details on the numerical methods used including the Matlab R13 codes used are available from the author upon request. The techniques proposed here reduce computation time by factor of 10 or more relative to the LP approach. In the estimation stage this amounted to computation time of one to two days instead of two-three weeks per run.

[11] In the borrowing and lending regime a non-concavity may occur at the wealth level at which agents are indifferent between being borrowers and lenders.

[12] The idea of possibly non-concave relationship between income and utility goes back at least to Friedman and Savage (1948).

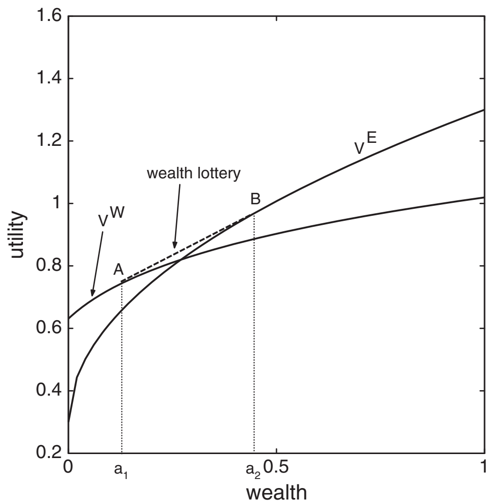

Fig. 1. Wealth lotteries.

Proposition 1 the optimal wealth lotteries are equivalent to allocation lotteries over consumption, investment, effort and output, i.e., instead of literal wealth lotteries these specifications can capture more general randomization elements in actual financial arrangements.

In the empirical analysis below I estimate and statistically test the three basic financial regimes with and without allowing for ex-ante wealth randomization.[13] In summary, I study six possible financial contract regimes:

1. Savings only without wealth lotteries (SNL)
2. Savings only with wealth lotteries (SL)
3. Borrowing and lending without wealth lotteries (BNL)
4. Borrowing and lending with wealth lotteries (BL)
5. Constrained insurance without wealth lotteries (INL)
6. Constrained insurance with wealth lotteries (IL)[14]

3. Computation

3.1. Functional forms

For numerical purposes I adopt the following preference and technology specifications:

$$u(c,z) = \frac{c^{1-\gamma_1}}{1-\gamma_1} - \lambda\frac{z^{\gamma_2}}{\gamma_2}$$
$$p^e(z,k) = \frac{k^\alpha z^{1-\alpha}}{1+k^\alpha z^{1-\alpha}} \quad \text{and} \quad p^w(z) = \frac{z}{1+z} \tag{16}$$

The utility function, $u(c, z)$ displays constant relative risk aversion in consumption represented by the parameter, $\gamma_1 \geq 0$.This is a generalization of the functional form used by Aghion and Bolton (1997) who impose risk neutrality ($\gamma_1 = 0$). Allowing for risk aversion has the important consequence of making the agents demand insurance in case of project failure, which not all of the financial environments I study are able to provide. The remaining preference parameters, $\lambda > 0$ and $\gamma_2 \geq 0$, determine respectively the relative disutility of effort and the degree of curvature in effort which also generalize the quadratic effort cost used by Aghion and Bolton. In the production (probability of success) function, the parameter $\alpha \geq 0$ determines the relative importance ('share') of investment and effort. The functional forms for p^e and p^w are flexible allowing effort and investment to be chosen on $[0, \infty)$ instead of restricting them to a closed interval. The advantage is that one need not worry about corner solutions which can make the interpretation of the results complicated or have no economic meaning.

In the baseline specification entrepreneurial ability, which is unobserved to the econometrician, is assumed to be distributed on the unit interval $[\kappa, \kappa+1]$ with the probability density function

$$\eta(\theta) = 2m(\theta - \kappa) + 1 - m \tag{17}$$

where $\kappa \geq 0$ and $m \in [-1, 1]$. The main rationale for this functional form is to minimize the number of estimated parameters and yet provide sufficient flexibility in the ability distribution. The parameter m characterizes the shape of the distribution that can be estimated from the data. When m equals zero, ability is uniformly distributed. When m is positive, more probability mass is put on high ability agents, while for negative m more mass is put on low-talent agents. The support parameter κ in turn determines the average ability in the economy and its range. In the benchmark estimation runs it is assumed that ability and initial wealth are uncorrelated but in the robustness section I also analyze the case in which ability can be correlated with wealth. I also perform robustness run in which ability is log-normally distributed.

3.2. Model predictions

Before estimating the model, I present simulations for *fixed* baseline parameters.[15] The purpose is to outline the salient features and differences across the regimes with regards to their predictions for consumption, investment, effort and occupational choice holding preferences, technology and entrepreneurial ability fixed. These differences form the basis of my empirical strategy in the next section.

I simulate the structural model under each of the savings only, borrowing and lending, and constrained insurance regimes for the following parameters: $\gamma_1 = .0825$, $\gamma_2 = 1.3426$, $\lambda = 1$, $\alpha = .5$, $q_h = 2.2116$, $w_h = 1.1058$, $m = .0741$ and $\kappa = .47$. These parameter values are not arbitrary; they are the actual maximum likelihood estimates for the BL regime (see Table 3b). A detailed description of how they are obtained is available in the next section. The simulations use actual wealth from the Thai data normalized on the interval [0,1].

To study how the optimal contracts differ as function of initial wealth I first fix entrepreneurial ability across the regimes by setting θ equal to the midpoint in its support, $\eta(\theta)$. For expositional clarity I focus on the entrepreneurs who are the agents affected by the financial constraints. Fig. 2 describes the optimal state-contingent consumption, $c_h(a)$ and $c_l(a)$, effort, $z(a)$ and net savings, $a - k(a)$ of entrepreneurs as function of initial wealth a in each of the three basic financial regimes with lotteries. In terms of consumption (the first row of panels) we see that the three regimes differ significantly in the degree of consumption smoothing provided represented by the difference in consumption across the two income states. These differences are most pronounced at low wealths, for the poorest and most constrained agents. The savings only regime (the top left panel) provides the least in terms of consumption smoothing as poor agents cannot borrow or share risk otherwise. The borrowing model (the middle panel) yields a smaller consumption differential for poor agents which is reduced further in the constrained insurance regime. Perfect consumption smoothing is not provided in the latter due to the moral hazard problem. The discontinuity in the borrowing regime at the wealth level for which entrepreneurs are just indifferent between borrowing at cost $R(a, \theta)$ and self-financing (at opportunity cost $r < R(a, \theta)$) occurs due to the binding limited liability constraint.

Entrepreneurial effort and investment (the second row of panels on Fig. 2) are both increasing in wealth due to the complementarity in

[13] In the no-lottery contracts the agent chooses with probability one the occupation that provides her with higher utility.

[14] This is the constrained-optimal financial contract in the model.

[15] In contrast, the MLE estimation naturally produces different best-fitting parameter estimates for each regime.

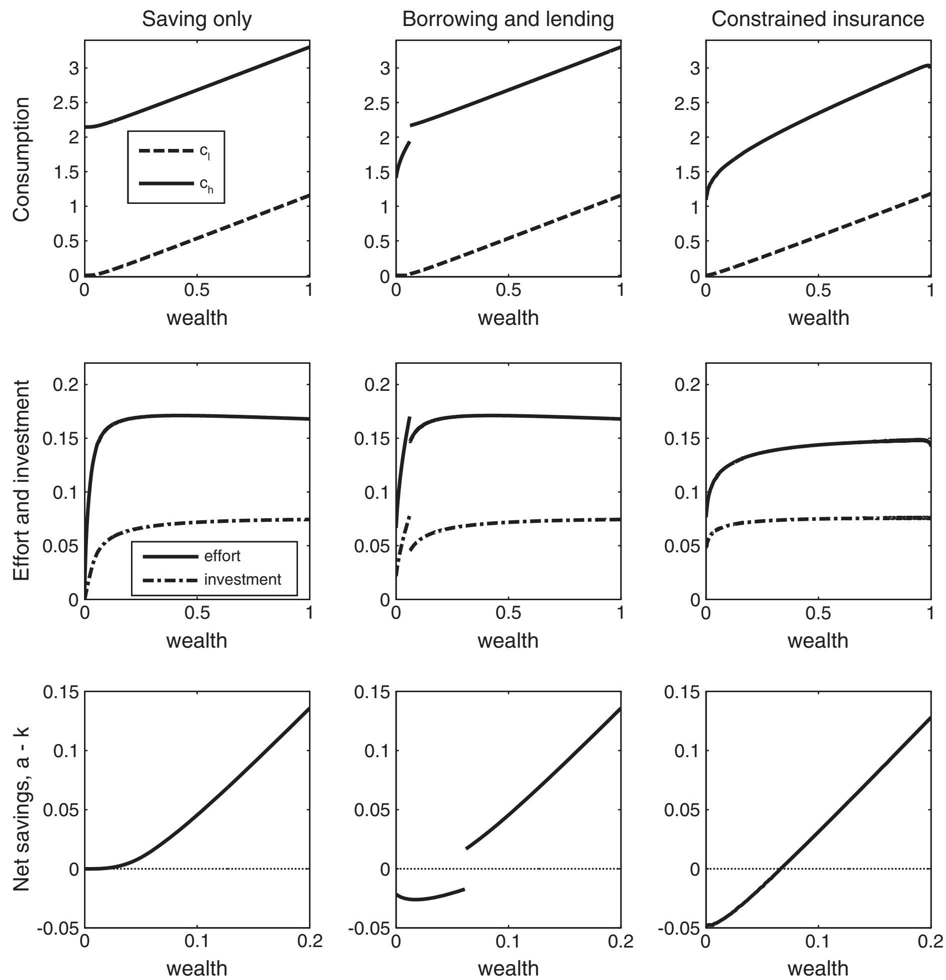

Fig. 2. Model predictions at fixed parameters, entrepreneurs.

production and the fact that investment becomes relatively less costly as more wealth is available (decreasing marginal utility of consumption). The main differences across the regimes are once again most pronounced for the poorest agents. Low-wealth borrowing entrepreneurs exert more effort and invest more relative to under saving only or constrained insurance.[16] The intuition for their incentive to exert more effort is to minimize the probability of bankruptcy and getting zero consumption due to the binding limited liability constraint in the borrowing and lending regime. The constrained insurance regime yields an almost flat investment function in wealth, that is, even very poor agents are able to invest close to the optimal amount. On the other hand, the better consumption smoothing results in lower effort exerted than in the savings only or borrowing regimes for the majority of initial wealth levels.

The third row of panels in Fig. 2 shows the behavior of net savings, $a-k(a)$ across the regimes (the wealth axis is truncated to [0,.2] to focus on the differences which again occur for low wealth levels where agents are constrained). In the savings only regime net savings are non-negative by definition. In contrast, in the borrowing regime net savings are negative at $a=0$, decrease in wealth for the poorest agents and then increase in wealth for richer agents. Intuitively, for low values of a the endogenous interest rate $R(a)$ is high due to the high probability of default (the agent is highly leveraged leading to low incentives to supply effort, the so-called 'debt overhang' moral hazard problem). As initial wealth goes up, the credit constraint relaxes and borrowing increases (net savings decrease) in wealth. As the agent gets even richer he needs to borrow less so net savings start increasing in wealth. In contrast, in the constrained insurance regime net savings are always increasing in wealth — 'borrowing' decreases in wealth since doing so relaxes the incentive compatibility constraint (see Paulson et al., 2006 for more details).[17] I come back to these model predictions on net savings in the non-parametric robustness Section 5.3.

Fig. 3 illustrates the model predictions under each financial regime with respect to occupational choice. It depicts the mapping between entrepreneurial ability (on the vertical axis), initial wealth (on the horizontal axis) and predicted occupation for each regime. Note that the poorest agents in the savings only regime are constrained to be workers (the areas in black) even at high ability levels while relatively low-ability but rich agents can start businesses. This leads to an inefficient allocation of investment resources. In a world of perfect financial markets agents would be sorted into the two occupations solely based on ability with the high θ agents being entrepreneurs and the low θ ones being workers. That is, the probability of starting a business would be uncorrelated with wealth. In all panels of Fig. 3, however, there is positive correlation between initial wealth and starting a business. Intuitively, in the incomplete financial markets settings studied here low-wealth agents are not able to start

[16] This result is similar in spirit to the "American dream" effect in Ghatak et al. (2001).

[17] This is in contrast to the Evans and Jovanovic (1989) model where investment is exogenously limited to a multiple of one's own wealth and borrowing always (weakly) increases in wealth.

businesses since they cannot borrow or, if they could, since their incentives to supply effort are low given that they would have a large part of their income taken by the bank as interest payment in case of success. The bank, of course, realizes that and responds by optimally adjusting the interest rate $R(a, \theta)$ or by rationing such agents out of the credit market.

Fig. 3 also illustrates the role of wealth lotteries for agents' occupational outcomes (the areas in gray in the panels on the right). The positive effect of the lotteries with respect to increasing entrepreneurship among medium- and high-ability agents is strongest for the savings only regime and for the least wealthy agents, that is, exactly where the financial constraints are most severe. More generally, the welfare effect of wealth lotteries is positive as they help some ex-ante poor agents become entrepreneurs which increases overall output and allocative efficiency.

In summary, the studied financial environments have significantly different implications about consumption, investment and occupational choice. These differences are most pronounced at low wealth levels.

4. Empirical analysis

In this section I estimate the financial regimes using data on rural households in Thailand via maximum likelihood. I first obtain a likelihood value for each regime and the corresponding estimates for the structural parameters. Next, the financial regimes are compared pairwise in order to identify the regime that comes closest to the observed pattern of entrepreneurship as function of wealth in the data.

This is a structural estimation and model comparison paper and naturally this poses the question of distinguishing between testing or rejecting the imposed model structure (functional forms) versus testing the actual relationships between the data variables we are interested in (the financial regimes). I deal with this issue in several ways. First, I use flexible, yet relatively simply parameterizable functional forms for preferences, technology and the unobservable talent distribution. These are held constant across the alternative regimes, i.e., any differences in likelihood are due to the nature of financial constraints imposed by the model, not due to differences in functional forms. Second, in the robustness section I explore alternative functional forms and parameterizations and perform the empirical analysis for data sub-samples stratified by wealth, region, and financial access. Runs with data simulated from the model are also performed to test the validity of the computational estimation methodology. Third, in Section 5.3 I supplement the maximum likelihood and Vuong test results with additional graphs, tables and non-parametric regressions to better illustrate and provide further supporting evidence for the robustness of the main results.

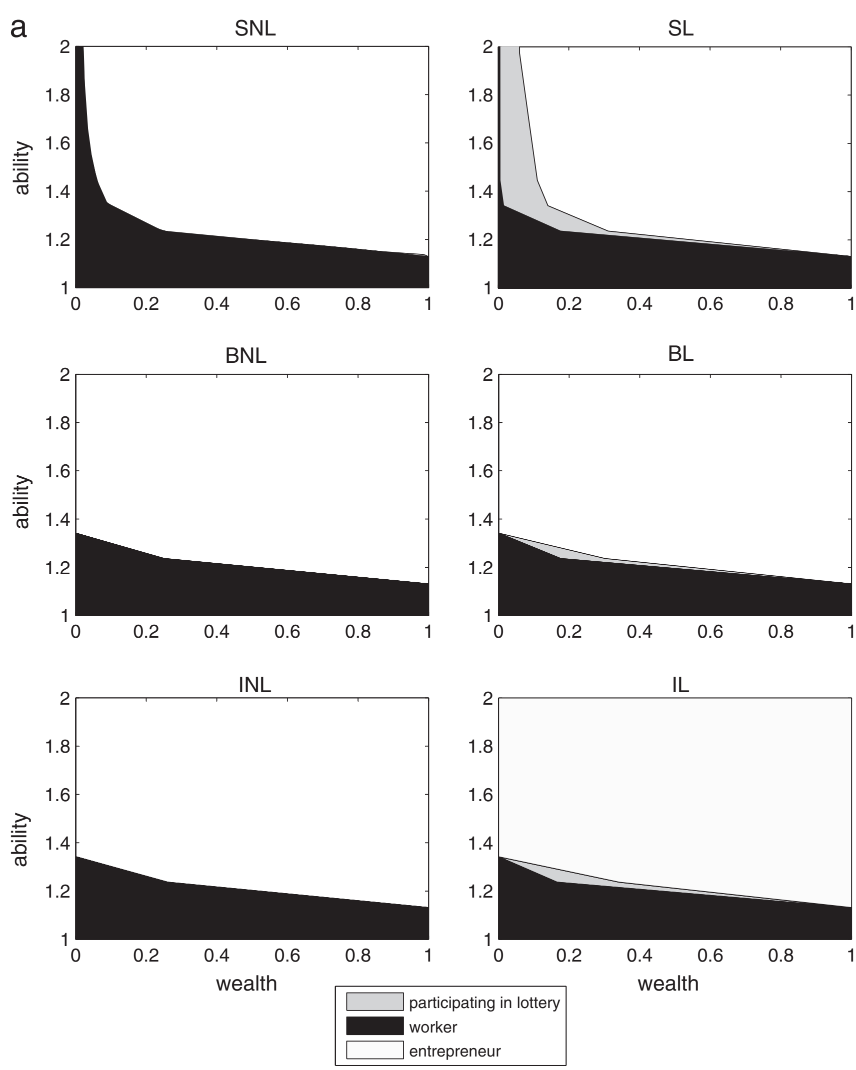

Fig. 3. a. Predicted occupational choice maps. b. Quantifying wealth lotteries.

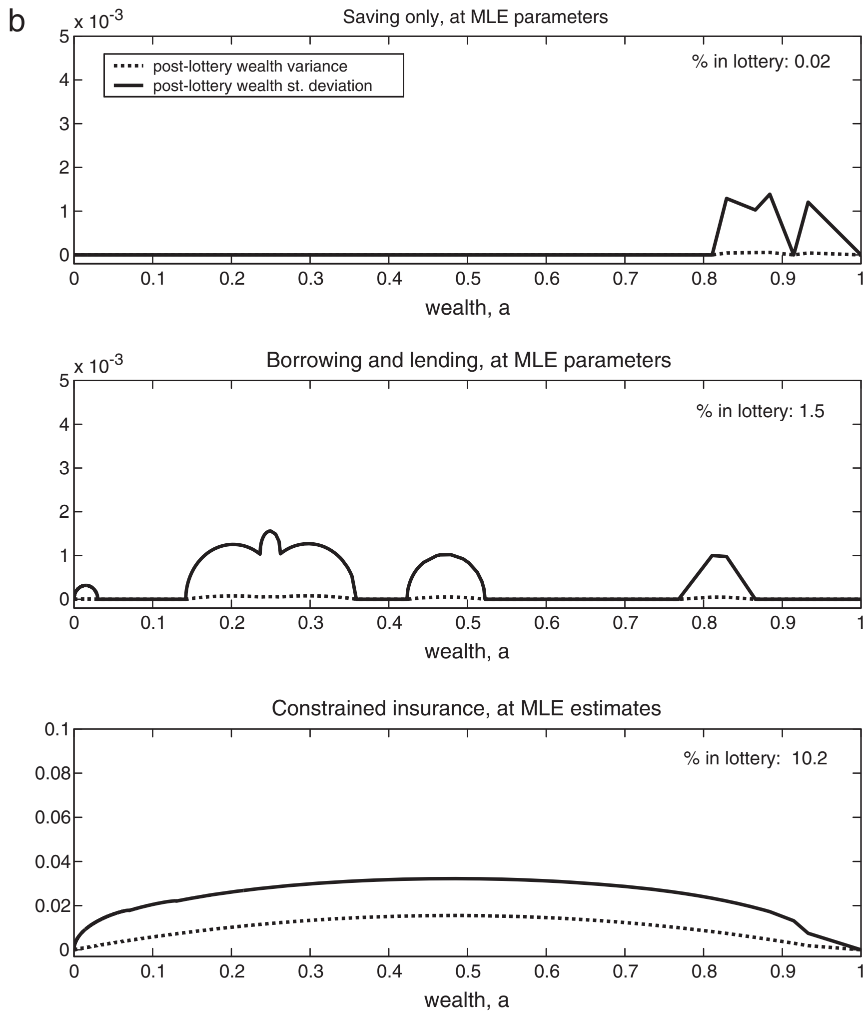

Fig. 3 (*continued*).

4.1. Data

The data comes from the Townsend Thai Surveys.[18] The baseline survey used here was fielded in 1997 in four *changwats* (provinces) located in two geographically and socioeconomically different regions of Thailand: the rural and semi-urban central region close to the capital Bangkok and the much poorer and more traditionally rural Northeastern region. The contrast between the survey areas is deliberate and has the obvious statistical advantages. A stratified random sample of twelve *tambons* (which usually include 10–12 villages) was selected within each changwat. Four villages were selected at random in each tambon and fifteen randomly chosen households were interviewed.

The sample used in this paper consists of 2313 households, about 14% of which were running own businesses at the time of the survey. Consistent with the model, a *business* is defined as any activity different from the default career choice of subsistence farming (predominantly rice) or wage work. Examples of businesses in the data are running a shop or restaurant, growing shrimp or livestock or provision of various services.[19] The idea is that an active decision to do something different from the default has been taken by the households defined as "entrepreneurs". The businesses in the sample are predominantly very small — 90% are operated within the family without hired labor. Shrimp or fish raising, shops and trade account for 70% of all businesses in the data with the rest of businesses falling across restaurants/noodle eateries, sewing, mechanical/repair, haircuts. laundry, etc., each accounting for 5% of the total or less.

The median initial investment needed to start a business is non-trivial and varies significantly with the business type but is relatively uniform across regions. Specifically, the median investment in a shop is around 16,000 baht or 15% of the 1996 Thai average annual income, the median initial investment in trade is around 21% of Thai average annual income, and the median initial investment in fish or shrimp varies between 8% and 49% of Thai average annual income depending on the region. About 60% of initial investment comes from savings, 9% from commercial bank loans, 7% from loans from the Bank for Agriculture and Agricultural Cooperatives (BAAC),[20] and the rest from various informal sources such as friends and relatives, money lenders, etc. The types of financial institutions and credit sources available in the villages and the contracts they offer thus resemble closely those in our theoretical framework. Formal savings and credit contracts offered by the banks fit into the saving and borrowing regimes while the more informal sources of finance, especially loans by friends

[18] For a detailed description of the survey, questionnaires and the data, see Binford et al. (2001) and the CIER website: http://cier.uchicago.edu.

[19] Admittedly this definition does not take into account some larger farms that may be effectively run as businesses. In Paulson et al. (2006) we performed various robustness checks (including random occupation assignments) with regards to the definition of business and found that the currently used definition is the most consistent relative to the model.

[20] The BAAC is a government-funded major credit institution in rural Thailand. It provides both individual, collateral-backed loans as well as group lending.

Table 1
Descriptive statistics, 1997 Thailand household survey data.

	Whole sample			Northeast			Central		
	Business	No Business	Total	Business	No Business	Total	Business	No Business	Total
Observations	320	1993	2313	111	1111	1222	209	882	1091
Percent of sample	14%	86%		9%	91%		19%	81%	
Mean wealth (1000 baht)	1466	653	765	451	380	386	2004	997	1190
St. dev. wealth (1000 baht)	2815	1450	1727	514	681	668	3342	1989	2342
Median wealth (1000 baht)	280	200	205	215	180	180	306	245	253
Wealth skewness	2.99	5.29	4.82	1.38	7.41	7.19	2.27	3.8	3.41
Min wealth (1000 baht)	1	0.02	0.02	1	0.02	0.02	1.2	0.5	0.52
Max wealth (1000 baht)	16400	15000	16400	2134	12600	12600	16400	15000	16400
Mean wealth (with fin. access)	1770	917	1055	535	473	479	2362	1413	1618
Mean wealth (no fin. access)	1107	436	515	366	311	315	1549	609	767
Percentages									
Wealth below median	13%	87%		8.8%	91.2%		17%	83%	
Wealth above median	15%	85%		9.3%	90.7%		21%	79%	
Financial access	16%	84%	46%[a]	11%	89%	43%[a]	22%	88%	50%[a]
No financial access	12%	88%	54%[a]	8%	92%	57%[a]	17%	83%	50%[a]

[a] Percentage of the total number of observations in the stratification.

and relatives, are typically more contingency-based like in the constrained insurance specification.

The sample contains only businesses started within the five years prior to the survey. This was done to obtain a more accurate assessment of the process of transition into entrepreneurship. Consistent with that, the household wealths in the data (initial wealth, a in the model) correspond to six years *prior to* the survey date, that is, to wealth prior to choosing whether to start a business.[21] This is important to tackle possible endogeneity issues.[22] The value of any business assets that the household may have owned six years ago is excluded to control for previous business history. All non-positive wealth observations, as well as the outlier observations in the top wealth percentile were removed from the original sample for computational and statistical reasons.

The survey data also include information on access to and use of various formal and informal financial institutions measured at the time of the survey. Theory suggests that these are important determinants of the household's choice of occupation. I use the variation in these characteristics, as well as by region and by wealth, to test the relative likelihood of the financial regimes, anticipating that different regimes may fit best in different data stratifications.

Table 1 presents summary statistics of the data. The distribution of household wealth is highly skewed to the right with the median wealth much lower than the mean. This should help in distinguishing among the financial regimes — remember from Section 3.2 that the biggest differences in their predictions occur at low wealth, where agents are most affected by the various financial constraints. The fraction of businesses is positively correlated with initial wealth with correlation coefficient 0.16. Thirteen percent of the agents with initial wealth below the median run a business, while this percentage among those with wealth above the median is fifteen.

The average initial wealth of agents with financial access is about two times higher than that of agents without financial access. Agents with financial access are also characterized with a higher fraction of entrepreneurs (16%) compared to the ones without financial access (12%). On average entrepreneurs have initial wealth two times larger than that of workers. As already mentioned, the North-East region is much poorer than the central region (the mean wealth is 3.5 times lower) and has a highly skewed wealth distribution. There are also much less entrepreneurs in the North-East compared to the central region (9% versus 19%) which is consistent with the presence of stronger financial constraints. As in the aggregate data, entrepreneurship is increasing in wealth and access to credit in both regions.

4.2. Estimation technique

I estimate the model by maximum likelihood. What is fitted is the probability of being entrepreneur as a function of wealth and ability generated by the model under each of the financial regimes with the actual household occupational status from the data.[23] Since there is no data on entrepreneurial ability, I assume that θ is unobserved by the econometrician but follows a known distribution, $\eta(\theta)$.For the baseline runs, η has the form (Eq. (17)), the parameters of which, κ and m are estimated along with the technology and preference parameters. In the robustness section I also consider log-normally distributed ability. Additionally, in the baseline specification current entrepreneurial ability is assumed independent from initial wealth (wealth six years ago). I relax this assumption in the robustness section.

[21] The initial wealth measure is based on the past value of all household assets including real assets and land. The past value of real assets is found by depreciating the asset purchase price (in 1997 baht) from the time of purchase to what it would have been worth six years prior to the survey. The depreciation rate used for all household and agricultural assets is 10% per year. For example, if the household purchased a tractor ten years before the survey for 100,000 baht, we would first convert the purchase price to 1997 baht (using the Thai consumer price index) and then multiply this figure by $.9^4$ to account for four years of depreciation between the purchase data and six years prior to the survey. This procedure gives the value of the tractor six years prior to the survey. Regarding past values of land, households were asked to report the current value of each plot that they own. In calculating past land values, we assume that there have been no real changes in land prices. So if the household has had one plot for ten years and the current value of that plot is 100,000 baht, then six years ago the value of that plot will also be 100,000 baht (in 1997 baht). In addition land purchase and sale information is used to measure the value of land that a household owned in the past.

[22] Looking only at businesses established within the five years before the survey (and not before that) provides the advantage of a more accurate measure of ex-ante wealth. Admittedly, using *t-6* wealth cannot completely rule out the possibility that some unobservable variables co-determine wealth and entrepreneurship (note however that the model allows for differential ability) or that agents at *t-7* may expect to become entrepreneurs later on and accumulate wealth in response. In an earlier draft I did a run with businesses started 10 years ago (at the cost of loss of sample size) and the results remained robust.

[23] Ideally, more dimensions of the model (e.g., consumption or investment patterns, future wealth, etc.) could be incorporated in the estimation procedure. Data limitations and computational problems at the time of writing have prevented this in the current paper which focuses on the role of initial wealth for business start-ups. We attempt to address some of these possibilities in Karaivanov and Townsend (2010).

Table 2
Savings only.

Stratification	logL	Parameter estimates				
		γ_1	γ_2	q_h	m	κ
a. Savings only, no wealth lotteries (SNL)						
Whole sample	−0.3945	0.0774	1.1999	0.5001	−0.0212	2.5057
		(0.0000)	(0.0000)	(0.0000)	(0.0004)	(0.0000)
Central	−0.4905	0.0993	1.1387	0.5195	−0.6469	2.9102
		(0.0002)	(0.0021)	(0.0009)	(0.0013)	(0.0035)
Northeast	−0.3046	0.0649	1.1293	0.5194	−0.3123	2.0604
		(0.0006)	(0.0079)	(0.0111)	(0.0028)	(0.0087)
Wealth below median	−0.3787	0.0993	1.1075	0.4991	−0.9687	2.9723
		(0.0005)	(0.0014)	(0.0013)	(0.0083)	(0.0031)
Wealth above median	−0.4272	0.1050	1.4038	0.5688	−0.8293	1.8500
		(0.0000)	(0.0021)	(0.0009)	(0.0018)	(0.0045)
b. Savings only, with wealth lotteries (SL)						
Whole sample	−0.3988	0.0804	1.1715	0.5199	0.1515	2.5553
		(0.0003)	(0.0077)	(0.0021)	(0.0011)	(0.0323)
Central	−0.4885	0.1009	1.0456	0.9297	0.7037	3.0003
		(0.0024)	(0.0074)	(0.0074)	(0.0288)	(0.0417)
Northeast	−0.3045	0.0807	1.1713	0.5198	−0.2574	2.5558
		(0.0002)	(0.0048)	(0.0011)	(0.0006)	(0.0046)
Wealth below median	−0.3791	0.0803	1.1722	0.5200	0.0526	2.5520
		(0.0007)	(0.0287)	(0.0201)	(0.0006)	(0.0206)
Wealth above median	−0.4099	0.1000	1.1998	1.5010	−0.9062	1.0005
		(0.0009)	(0.0195)	(0.0062)	(0.0085)	(0.0542)

Note: Bootstrap standard errors in the parentheses.

The log-likelihood function used to fit predicted to actual occupational choice in each regime is,

$$L(\phi) \equiv \frac{1}{N} \sum_{i=1}^{N} E_i \ln H(a_i | \phi) + (1-E_i) \ln(1-H(a_i | \phi))$$

where N is the number of observations, E_i is a binary variable which takes the value of 1 if agent i is an entrepreneur in the data and 0 otherwise, a_i is the wealth of agent i in the data, ϕ is the vector of model parameters $(\gamma_1, \gamma_2, \lambda, q_h, \alpha, m, \kappa, w_h, r)$ as defined in Section 3.1, and $H(a_i|\phi)$ is the expected probability of being entrepreneur generated by the model for an agent with wealth a_i obtained integrating over the distribution of entrepreneurial ability $\eta(\theta)$.

Table 3
Borrowing and lending.

Stratification	logL	Parameter estimates				
		γ_1	γ_2	q_h	m	κ
a. Borrowing and lending, no wealth lotteries (BNL)						
Whole sample	−0.3921	0.3996	0.8994	2.9968	−0.0014	1.0225
		(0.0038)	(0.0044)	(0.0246)	(0.0002)	(0.0456)
Central	−0.4790	0.4119	0.8947	2.9876	0.0587	0.9797
		(0.0084)	(0.0068)	(0.0402)	(0.0127)	(0.0445)
Northeast	−0.3032	0.9122	0.1020	2.8497	0.2450	0.0000
		(0.0032)	(0.0045)	(0.1267)	(0.0582)	(0.0002)
Wealth below median	−0.3791	1.2000	1.5000	1.0000	0.8779	3.0375
		(0.0016)	(0.0007)	(0.0035)	(0.0197)	(0.0162)
Wealth above median	−0.4046	0.4014	0.8909	2.9973	−0.0597	1.0075
		(0.0083)	(0.0038)	(0.0296)	(0.0027)	(0.0165)
b. Borrowing and lending, with wealth lotteries (BL)						
Whole sample	−0.3918	0.0825	1.3426	2.2116	0.0741	0.4700
		(0.0061)	(0.1866)	(0.1113)	(0.0550)	(0.0258)
Central	−0.4754	0.0543	0.0622	0.4996	−0.8137	1.1509
		(0.0005)	(0.0005)	(0.0070)	(0.0198)	(0.0328)
Northeast	−0.3045	1.6772	1.2951	2.2937	−0.2574	1.7591
		(0.0106)	(0.0082)	(0.0144)	(0.0042)	(0.0278)
Wealth below median	−0.3783	0.3576	2.2434	3.1850	−0.9118	0.4193
		(0.0238)	(0.0727)	(0.1015)	(0.0606)	(0.0152)
Wealth above median	−0.4046	0.0542	0.0622	0.4997	−0.9758	1.1512
		(0.0008)	(0.0007)	(0.0051)	(0.0430)	(0.0118)

Note: Bootstrap standard errors in the parentheses.

Table 4
Insurance.

Stratification	logL	Parameter estimates				
		γ_1	γ_2	q_h	m	κ
a. Insurance, with wealth lotteries (INL)						
Whole sample	−0.3947	0.3963	1.5294	3.1712	−0.5533	0.5008
		(0.0237)	(0.0341)	(0.0199)	(0.0449)	(0.0091)
Central	−0.4777	0.8429	2.3952	4.1898	−0.2844	0.3498
		(0.0716)	(0.1180)	(0.0791)	(0.0792)	(0.0073)
Northeast	−0.3008	1.3288	1.8533	2.0746	−0.7538	0.8656
		(0.0602)	(0.0351)	(0.0151)	(0.0229)	(0.0520)
Wealth below median	−0.3791	0.8410	2.9950	4.9945	−0.8252	0.5293
		(0.0220)	(0.0287)	(0.0549)	(0.0293)	(0.0069)
Wealth above median	−0.4099	0.7788	2.0001	1.5003	−0.5845	0.9995
		(0.0434)	(0.1219)	(0.0502)	(0.0618)	(0.0564)
b. Insurance, with wealth lotteries (IL)						
Whole sample	−0.3912	1.4312	0.9408	3.0682	−0.5177	1.1174
		(0.0133)	(0.0035)	(0.0315)	(0.0079)	(0.0033)
Central	−0.4733	0.4009	1.4679	1.9989	−0.6853	1.0060
		(0.0130)	(0.0344)	(0.0503)	(0.0405)	(0.0281)
Northeast	−0.3039	0.3998	0.9086	2.9927	−0.5036	0.9917
		(0.0103)	(0.0056)	(0.0151)	(0.0077)	(0.0033)
Wealth below median	−0.3790	1.4348	0.9365	3.0609	−0.5194	1.1215
		(0.0244)	(0.0072)	(0.0332)	(0.0087)	(0.0183)
Wealth above median	−0.4011	0.0789	1.5109	1.4384	−0.9195	1.0037
		(0.0005)	(0.0160)	(0.0130)	(0.0111)	(0.0065)

Note: Bootstrap standard errors in the parentheses.

For computational reasons, in the baseline specification I fix the values of certain parameters. Namely I normalize $\lambda = 1$, I set $\alpha = 0.5$ and calibrate $w_h = q_h/2$ from the observation that entrepreneurs earn on average about twice as much as workers in the data. The gross interest rate r is set to 1.25, also calibrated from the data. The remaining parameters, γ_1, γ_2, q_h, m and κ are estimated. In the robustness section I also present results where the above restrictions are relaxed and eight parameters are estimated.

The likelihood maximization is performed separately for each financial regime with its corresponding function $H(a_i|\phi)$. Specifically, given wealth a_i from the data normalized on (0, 1], each model regime generates a value, between zero and one, for the probability that an agent with such wealth is an entrepreneur given the assumed financial structure and entrepreneurial ability distribution. Maximizing the likelihood identifies the structural parameters providing the best match between the model-generated probability of being in business and the actual occupation status in the data. The full details of the numerical algorithm used in the likelihood maximization can be found in Appendix C.

4.3. Testing

The likelihood values for each financial regime are next used to perform a formal statistical test of how well the alternative financial regimes fit the observed occupational choice pattern in the data. To test across the regimes I use bilateral statistical tests based on the Kullback–Leibler Information Criterion (KLIC).

The first criterion for regime comparisons I use is based on Akaike (1973). It simply states that, in a bilateral comparison, the model with the higher likelihood value provides better fit with the data compared to the model with the lower likelihood. This test is thus solely based on the sign of the difference between the likelihood values. As such it is subject to the criticism that it is deterministic in nature, while in reality the test result may be a random outcome and hence a small enough negative or positive difference between the likelihoods may not be statistically significant to reject the claim that the two compared models fit the data equally well.

The test proposed by Vuong (1989) which is the main model comparison test I use here addresses the issues with the Akaike test by

Table 5
Financial regime comparisons — baseline.

N	% business	Stratification	Comparison Z-statistics								
			Contracts Without Lotteries			Contracts With Lotteries			Lottery vs No Lottery		
			SNL vs BNL	SNL vs INL	BNL vs INL	SL vs BL	SL vs IL	BL vs IL	SNL vs SL	BNL vs BL	INL vs IL
2313	13.8%	Whole sample	−0.672	0.232	0.764	−2.549**	−2.911***	−0.263	1.421	−0.223	−1.382
1091	19.2%	Central region	−1.738*	−2.322**	−0.230	−2.528**	−2.708***	−0.878	−0.338	−0.666	−1.471
1222	9.1%	Northeast region	−0.439	−1.264	−1.226	−0.877	−0.564	−0.521	−0.072	0.263	1.490
1157	12.6%	Wealth below median	0.393	0.390	−0.946	−0.633	−0.785	0.579	0.402	−0.628	−1.141
1156	15.1%	Wealth above median	−2.727***	−1.658*	0.773	−0.863	−2.093**	−1.306	−3.461***	−0.002	−1.961**
1927	12.8%	No formal credit	−2.743***	−2.874***	0.269	−3.262***	−3.435***	−1.325	−0.116	0.644	−1.093
386	19.2%	Formal credit	−0.011	0.003	0.025	−0.818	−0.465	0.510	0.511	−0.586	−0.473
1388	16.1%	Any debt	−2.254**	−3.089***	−0.621	−2.347**	−2.669***	−1.390	−1.796*	−0.044	−0.183
925	10.4%	No debt	−1.341	−0.813	1.599	−1.170	−1.009	0.038	−0.032	−0.018	−1.075

A positive value means that the regime listed first in the comparison provides better fit according to the Akaike (1973) criterion, a negative value means that the regime listed second provides best fit.
*** Significant at the 1% confidence level under the Vuong (1989) test.
** Significant at the 5% level.
* Significant at the 10% level.

setting the model selection in a hypothesis testing framework. In view of the highly stylized models of financial constraints used here its main advantage is that it allows for both compared models to be misspecified. The null hypothesis is that the two models are equally likely to have generated the observed data. The Vuong test involves computing a modified likelihood ratio test statistic which, when the compared models are non-nested, is asymptotically distributed as standard Normal under the null hypothesis.[24]

5. Results

5.1. MLE parameter estimates

The results of the maximum likelihood estimation of the model regimes are presented in Tables 2-4. Looking at the parameter estimates, we see that those for the risk aversion coefficient, γ_1 tend to be lower for high-wealth stratifications (central region or wealth above median) in most regimes, especially BL and BNL, indicating a decrease in relative risk aversion with wealth on average. In all cases the parameter γ_1 is fairly accurately estimated indicating that its variation across the data stratifications is statistically significant. The estimated risk aversion for the whole sample is relatively low — not higher than 1.43. In most of the estimation runs the effort disutility curvature parameter γ_2 is larger than 1 suggesting high aversion to changes in the effort level.

The estimates of the preference parameters vary by wealth and region which is a further illustration of the structural differences across the financial environments: different parameters values are needed to produce the occupational patterns matching those in the common data. This also demonstrates that the interplay between productivity and wealth effects could potentially affect the demand for credit as function of wealth. Allowing for wealth lotteries does not seem to affect much the curvature parameter estimates in most cases. The technology parameter q_h is estimated to be between .5 and 3 across the various regimes and data sub-samples, indicating that high returns on investment are possible in case of success (remember initial wealth is normalized on [0,1]).

Next look at the estimates of the parameters governing the support and shape of the talent distribution — m and κ in the baseline.

[24] The structural models studied here are statistically non-nested. Formally, following Vuong (1989), model A nests model B, if, for any possible allocation that can arise in model B, there exist parameter values such that this is an allocation in model A. The Vuong model comparison test can be also used for “overlapping” models (neither strictly nested nor non-nested) in which case the test statistic has a weighted sum of chi-squares distribution under the null (see Vuong, p. 322).

In most cases m is negative, implying that the estimated entrepreneurial ability distribution puts more mass on low-ability agents. The estimates do not seem to vary in a systematic way with wealth. However, some of the standard errors are relatively large so such differences may not be statistically significant. Looking at the estimates for the parameter κ which governs the range or level of ability, we see a discernible difference between the estimates for the savings regime (around 2.5) compared to those in the borrowing and insurance settings (around 0.5–1). The likely reason is that, for the same value of κ, the savings regime predicts much lower probability of starting a business, especially at low wealths, compared to the other regimes (remember Fig. 3).

5.2. Financial regime comparisons — Vuong test

Table 5 reports the results from statistical model comparison tests for nine data stratifications based on region, wealth, debt and access to formal credit. The various data stratifications can be viewed as introducing control variables that are outside the structural model in the maximum likelihood framework. The purpose of the comparison is to try to identify the best fitting financial regime in each stratification and study how (if at all) this varies by wealth, region, or access to financing.

The models with and without randomization are first compared among each other, which is followed by studying the effect of including wealth lotteries within each of the three basic financial regimes. The numbers in Table 5 indicate the significance of the test statistic according to the Akaike and Vuong tests. A positive value means that the regime listed first in the comparison pair provides better fit to the data according to Akaike's (1973) criterion. A negative value means the opposite. The significance of the Vuong test is indicated by the number of asterisks with the sign once again indicating which regime is the best fitting.

The savings only with no lotteries regime (SNL) is rejected as equally likely with respect to the data when compared to both the borrowing and insurance regimes in almost all data stratifications according to the Akaike test (columns 4 and 5 in Table 5). This suggests that the particular form of financial constraints it imposes is farther from the data generating process than the financial constraints associated with the borrowing and insurance regimes. The more conservative Vuong test results in rejection of the saving regime in four of the nine stratifications, pinpointing more precisely where the restrictions imposed by it fail in matching the data. This happens predominantly in the sub-samples characterized with higher wealth and higher degree of entrepreneurship — in the Central region, wealth above the median, and for households carrying debt. Significant differences are also found with respect to access to formal credit. Interestingly, the savings regime is not rejected (and in fact provides better fit according to the Akaike criterion) for agents with wealth below the median. It is also not rejected by the Vuong test in other low-wealth stratifications with fewer businesses ("no debt" and North-East).

The overall rejection of the saving only regime is even stronger for its lottery (SL) specification (see columns 7 and 8 in Table 5). The Akaike criterion rejects the SL regime in favor of BL and IL in all nine stratifications (all signs are negative) while the Vuong test statistics are significant for the stratifications "whole sample", "central region", "no formal credit", "any debt" and, for IL only, "wealth above the median". The savings regime is strongly rejected for agents holding debt but not for those without debt, which is consistent with the model. These results show evidence of structural differences in the nature of financial constraints operating in different regions and at different levels of wealth.[25]

Comparing the borrowing vs. the constrained insurance regime the Vuong test cannot reject the null hypothesis that they are equally close to the wealth/occupation pattern across all data stratifications (see columns 6 and 9 in Table 5). The Akaike criterion also does not reveal a discernible pattern — the signs of the test statistics vary, for example, BNL achieves higher likelihood than INL but IL achieves higher likelihood than BL for the whole sample. These results suggest that the financial constraints operating in the data as observed through their effect on occupational choice are likely less strict than those imposed by the savings only regime and closer to those under the insurance and borrowing regimes. The BL regime achieves better fit with the data than the IL regime (significant according to the Akaike test) for the sub-sample of households with access to formal credit while the opposite is true for the households without formal credit (column 9 of Table 5). As contingency type contracts such as those in the insurance regime are more likely to be present in informal loan arrangements as opposed to bank credit, this finding is also consistent with the model.

The result that the data reject the restrictive saving only regime but cannot reject the borrowing and lending and insurance regimes in favor of one other is consistent with the evidence for the presence of partial insurance over and beyond self-insurance in village economies (Townsend, 1994 and 1998). From theoretical standpoint the failure to reject the borrowing and constrained insurance regimes between each other is also in line with the results of Zame (1993) or Dubey et al. (2005) who show that allowing for default in an incomplete market setting (such as my borrowing regime) can attain allocations close to the information-constrained optimum (the insurance regime).

The last three columns of regime comparisons in Table 5 study the effect of allowing for randomization via wealth lotteries in each regime. From Section 2 we know that allowing such randomization affects the model predictions about occupational choice for certain wealth range where their value function is convex (see Fig. 1). Columns 10–12 of Table 5 show evidence that the financial regimes with randomization provide better fit with the data according to the Akaike criterion compared to their versions without lotteries — the majority of signs are negative although these results are not as strong as those on the rejection of the saving only regime earlier. Most Vuong test statistics are not significant at the 10% level but in all specifications for which they are significant the results point to the rejection of the regimes without randomization.

What mechanisms or institutions might serve the randomization role in practice? One possibility, widespread in developing countries, is the so-called 'rotating savings and credit associations' (roscas), which allow individuals to pool resources and use lottery to assign the pool to one of them, for example to buy a durable consumption good (TV, refrigerator, etc.) or a productive asset (walking tractor, motorcycle, etc.)[26] Gambling, including playing state lotteries is another possible randomization mechanism, especially among the poor. For instance, Miller and Paulson (2000) show that more than 40% of households who participated in the 1988 and 1990 Thai Socio-economic Surveys report positive expenditure on gambling the previous month. Gambling amounts to 4% of monthly expenditures among those households.[27] Allowing randomization in the model may be also proxying for the possibility that not all households are completely specialized by occupation as this within-household aspect is not modeled here. Certain functions performed by extended families may also lead to observationally equivalent results, e.g., if families can side-contract and direct resources toward the able but initially poor who are short of the business start-up threshold.

Going back to the earlier discussion in Section 2, one should not take the results in Table 5 as literally suggesting the existence of wealth lotteries in the Thai villages. The lotteries may pick up evidence for randomization elements in the financial arrangements households use. The better fit by the lottery regimes could be also due to unobserved heterogeneity in the data. If such heterogeneity exists and is incompletely explained by the NL regimes, the randomization inherent in the lottery settings may achieve better explanatory power.

While randomization is shown to weakly improve the model MLE fit with occupational choice data, its impact may be quantitatively small in terms of actual variation in consumption, investment, etc. it induces.[28] To quantify this, on Fig. 3b I plot pre-randomization wealth a (by definition equal to expected post-lottery wealth) against the expected variance and standard deviation of post-lottery wealth for each of the three baseline financial regimes with lotteries, integrated over the ability distribution. Each panel of the figure is computed at the respective MLE parameter estimates from Tables 2–4.[29]

Fig. 3b shows that, in the SL and BL regimes at the best-fitting MLE estimates, few agents participate in ex-ante lotteries over wealth and for those who do, the induced standard deviation in post-lottery wealth (and hence, in consumption, effort, investment, etc. as functions of a, see Fig. 2) is insignificant. In contrast, the panel for the constrained insurance (IL) model shows an expected number of lottery participants of around 10% at the MLE estimates. This is the only case on Fig. 3b in which there is some evidence for randomization potentially playing non-trivial role empirically. Still, the variance of post-lottery wealth is small relative to the level of initial wealth a for which it is induced (a maximum value of .015 at $a=.5$).

[25] These findings are consistent with the results of Ahlin and Townsend (2007).

[26] Roscas have been studied extensively from both the theoretical and empirical sides (see Besley et al., 1993; Besley and Levenson, 1996 among many others). Technically, the wealth randomizations I consider here are not exactly roscas since the latter usually last more than one period and each agent eventually wins the pot. Nevertheless, in the presence of time discounting, the fact that in any given week or month a single agent receives the pool (wins the lottery) while others pay into it (lose the lottery) I believe carries the main point.

[27] Sociologists have also documented the emergence of games-of-chance institutions ("numbers gambling") in poor black communities with limited access to credit (Light, 1977). Playing the government lottery, despite a significant negative expected return is very popular among poorer people (e.g., Clotfelter et al., 1999). Of course, other motives for gambling such as preference for status are also possible.

[28] I thank an anonymous referee for this observation.

[29] I computed each regime for each wealth level a in the data and for 50 levels of ability θ uniformly spread over the support $[\kappa, 1+\kappa]$ determined by the MLE estimate of κ. For each (a, θ) the model predicts whether such agent participates in a wealth lottery or not and what are his post-lottery wealth levels and their corresponding probabilities (Fig. 1). These are used to compute the variance of post-lottery wealth via the formula for binomial distribution. Then I numerically integrated over unobserved ability θ using the MLE estimates of m and κ to obtain the average fraction of agents (a, θ pairs) that participate in lotteries (reported on the graph) and the expected variance and standard deviation of post-lottery wealth.

Table 6
Actual and average predicted number of entrepreneurs by wealth quartile (Monte Carlo simulations at the MLE estimates, whole sample).

	Data	Model regimes					
		SNL	SL	BNL	BL	INL	IL
Q1	79	58.3	77.9	68.7	77.0	69.3	73.4
Q2	67	67.9	78.7	69.1	89.0	69.7	73.2
Q3	56	67.5	78.0	68.7	71.0	69.3	70.3
Q4	118	130.2	82.9	137.6	101.0	113.0	109.5
Total	320	323.9	317.5	344.1	338.0	321.3	326.4

5.3. Financial regime comparisons — non-parametric and other

This section present further analysis and evidence supporting the structural regime comparison results that try to reach inside the 'black box' of the omnibus maximum likelihood approach and help highlight precisely where the different regimes fail or succeed in fitting the data. I use data drawn from the models by Monte Carlo simulations at the MLE parameter estimates and further characterize the fit of the regimes using tables, graphs and non-parametric techniques.[30]

I first compare the ability of the different regimes to fit the observed occupational choice data by computing the predicted number of entrepreneurs by wealth quartile. I do 500 Monte Carlo runs drawing occupational status (0 or 1) at all wealth levels in the data for each regime evaluated at the respective MLE parameter estimates from Tables 2–4. I then compute the average (over all runs) predicted number of entrepreneurs and compare these predictions with the actual numbers in the data. This provides more detailed information on the ability of the regimes to fit the data than that contained in the overall likelihood value by indicating why and for what wealth levels each regime succeeds or fails in matching the data. Table 6 exhibits the actual (the column "data") and predicted number of entrepreneurs for each regime by wealth quartiles for the whole sample. We see that the SNL and BNL regimes fail to match the data for different reasons — the former underpredicts the number of entrepreneurs in the first wealth quartile, while the latter greatly overpredicts the number in the richest quartile and overall. The SL regime comes close to the data in terms of the total number of businesses but severely underpredicts entrepreneurship in the top quartile while the INL regime cannot match the change in entrepreneurship over the first three wealth quartiles. Consistent with the likelihood comparisons, the borrowing and insurance regimes, especially BL and IL, do the best job in matching the pattern of entrepreneurship as function of wealth in the data. In particular, only these two regimes are able to generate the decline in the number of entrepreneurs between the second and third quartile, followed by a sharp increase in the fourth.

Fig. 4 uses the simulated occupations data from the 500 Monte Carlo runs for each regime and plots a non-parametric (loess) regression line of the predicted fraction of businesses by each regime. On each panel the dotted line is the loess regression of the Thai occupational choice data on wealth, the solid line is the loess regression line of the simulated data, and the thin dashed lines are 95% confidence interval bounds. The circled (fuzzy) line plots the Monte Carlo run that minimizes mean square distance with the data loess regression line. The figure shows clearly why the saving only regime is rejected — SNL underpredicts entrepreneurship in the lower range of wealth while both SNL and SL underpredict the fraction of businesses at the top wealths. The saving only regime is also unable to match the increase in entrepreneurship at low wealths (up to $10^{-3.2}$) followed by a graduate fall over the mid-wealth range and another sharp increase at high wealths. Apparently, in rural Thailand it is easier to raise capital for entrepreneurial activities than would be predicted by a model with only savings.

In contrast, the figure illustrates why the borrowing and constrained insurance regimes with lotteries (BL and IL) fit the data best — the solid (simulation) and dotted (data) regression lines track each other very close, much closer than for the other regimes and over all wealth levels. The BL and IL regimes are also best able to generate the fall in entrepreneurship over medium wealth levels — notice that the green line corresponding to the best-fitting Monte Carlo draw of simulated data from each regime traces very closely the actual Thai data (the dotted line). Consistent with the previous findings, the regimes with randomization fit the data better than those without. These results show the robustness of the conclusions from the likelihood approach — remember, the MLE criterion is not equivalent to fitting the loess regression lines on Fig. 4 and yet the regime comparisons in Fig. 4 and Table 5 are very consistent.

Fig. 5 supplements Fig. 4 and Table 6 by plotting the fraction (over the 500 Monte Carlo runs) of correctly matched occupational choices for each regime, as function of wealth. Basically, I counted, over the 500 runs, the number of times for which the simulated occupation from the model at each wealth level matches the actual occupation in the data. The circles on the lines correspond to wealth deciles. The figure shows that top three regimes by likelihood achieve relatively good fit (over 70% of matched occupations) for the whole range of wealth below 10^{-1} where the majority of the data lie (89% of all observations). Notably, the fit does not deteriorate over the second and third wealth quartiles where the number of businesses is falling with wealth (the quartile wealth cutoffs are .003, .0125 and .04). Only in the last wealth decile the match rate worsens to around 60%. Consistent with the MLE results, the IL regime provides the highest fraction of matches over the wealth range with the majority of data. The comparison is mostly illustrative, since the maximum likelihood is correlated but not equivalent to maximizing the fractions plotted on the figure but it is re-assuring for the robustness of the structural findings.

Finally, Fig. 6 shows a non-parametric loess regression of net savings as function of wealth in the Thai data.[31] Going back to the theory section, remember that the insurance regime predicts that next savings start negative and always increase with wealth, while the borrowing regime allows negative net savings decreasing with wealth (see Fig. 2). Fig. 6 is consistent with these patterns and can be viewed as further, external validation to the Vuong test results. In contrast, the saving only regime does not allow negative savings.

5.4. Robustness

5.4.1. Allowing for correlation between wealth and entrepreneurial ability

An important concern in the entrepreneurship literature is the possible correlation between wealth and entrepreneurial ability. For example, when studying the relationship between going into business and wealth, some authors (e.g., Holtz-Eakin et al., 1994) use data on inheritances which are likely exogenous. Lacking such data I make an effort to control for endogeneity by using assets six years prior to the survey as the initial wealth variable in the model. However, the baseline assumption that the unobserved ability distribution is independent of wealth may still be potentially problematic. In this section I study the implications of relaxing this assumption by allowing correlation between ability θ and initial wealth a.

[30] Note that the analysis in this section should be interpreted mostly as illustrative since neither of the exercises I perform represents a formal way to statistically test the financial regimes.

[31] These data come from Paulson et al. (2006). Net savings are defined as the value of household financial savings plus loans owed to them minus current debt. Computational constraints and possible endogeneity issues prevent me from using net savings in the likelihood estimation.

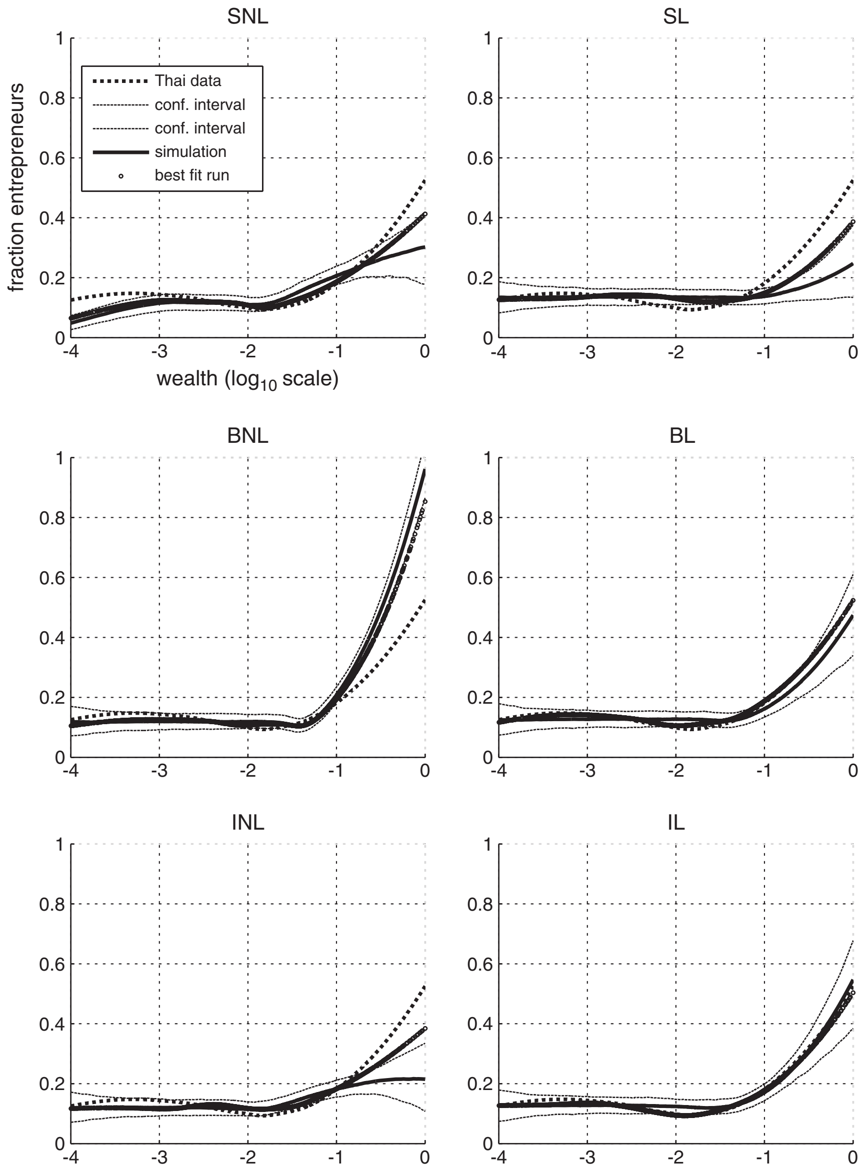

Fig. 4. Monte Carlo simulations — data and model at the MLE parameters (loess fit).

More formally, I modify the pdf of the ability distribution (Eq. (17)) to $\eta(\theta|a_i)=2(\theta-\kappa)m(a_i)+1-m(a_i)$, where $m(a_i)=\rho(2a_i-1)$ for each wealth observation a_i. As before, the functional form is chosen by the need for parsimony; adding extra parameters increases computational time exponentially. Here the new parameter ρ is to be estimated instead of the m in the baseline specification. The parameter ρ provides a measure of the correlation between wealth, a_i and ability, θ. Namely, when $\rho=1$, $m(a_i)$ is increasing from -1 to 1 as wealth goes up, i.e., more mass is shifted towards high ability agents indicating positive correlation between wealth and ability, while when $\rho=-1$ the opposite is true. At $\rho=0$ the ability distribution is uniform in wealth thus no correlation between a and θ is present.

I re-estimate all regimes using this specification. In all data stratifications for the SNL, BL and the insurance regimes the estimates of ρ are positive ranging between 0.3 and 0.8 indicating a moderate positive correlation between wealth and the implied measure of talent in the data.[32] About half of the estimates for the SL and BNL regimes are negative, however, showing these findings are not universal. Table 7 shows the results of the regime comparison tests. Observe that the baseline results remain robust to allowing correlation between wealth and ability. Once again, the savings regimes are rejected by the Akaike test in all but two cases (see columns 4–5 and 7–8 of Table 7). As before, the saving regimes are rejected by the Vuong test in the Central, 'wealth above median' and 'any debt' stratifications; the borrowing and insurance regimes are not statistically distinguishable; and the lottery regimes outperform the no-lottery regimes in the majority of cases (the test statistics are negative). The better fit of the borrowing regime compared to constrained insurance for households with access to formal credit is even more pronounced than in the baseline. Overall, despite some evidence of positive correlation ($\rho>0$) between entrepreneurial ability and wealth, allowing for this does not change in any significant way the previous conclusions about the nature of financial constraints in the various sub-samples and the fit of the alternative financial regimes relative to the data.

The finding that the ranking of the regimes is robust to allowing for correlation between wealth and talent may have consequences, however, if one considers policy implications. Indeed, if wealth and ability were uncorrelated, the fact that poorer households cannot start business implies that entrepreneurial ability is wasted. On the other

[32] The exact numbers are available from the author upon request.

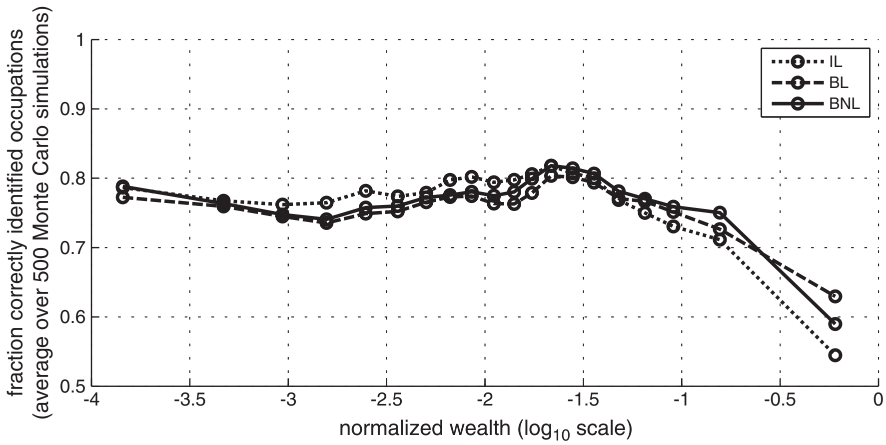

Fig. 5. Top three models by MLE fit. Fraction of correctly identified occupations by wealth.

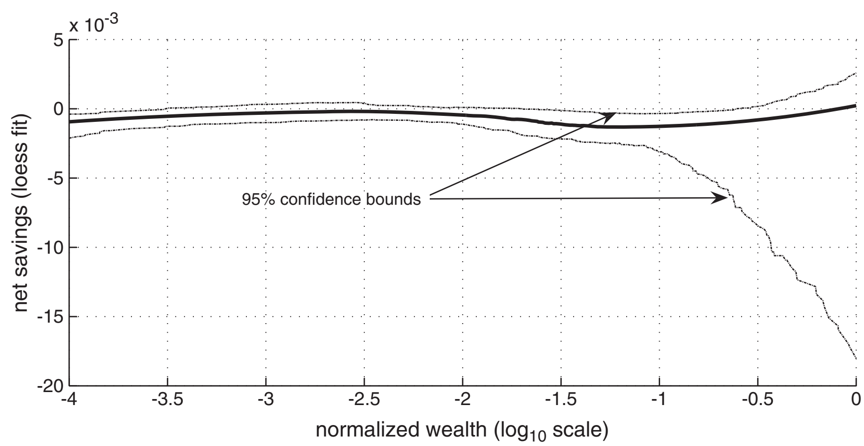

Fig. 6. Net savings as function of initial wealth.

hand, if mostly the richer people are of high ability, the fact that credit market imperfections cut off the poor from credit has less severe consequences from an efficiency standpoint.

5.4.2. Other robustness checks

- In the baseline estimation runs, some preference and technology parameters (λ, α and w_h) were held fixed for computational reasons. Table 7 shows the results of the regime comparisons with these three parameters estimated together with the five parameters from the baseline. The main findings remain robust although some are not so sharp as before, for example, note the insignificance of the Vuong statistics in the Central and "wealth above median" sub-samples in the SNL versus BNL comparison. On the other hand the values of the Vuong statistics in the lottery against no lottery comparisons are more often significant. The eight-parameter specification, however, is potentially prone to identification issues,[33] which is why I use the five estimated parameters specification as the baseline.
- The complexity of the models of financial constraints in this paper unfortunately does not allow direct analytical identification proofs. Thus, to further test the validity of my estimation methodology, I did an estimation run with simulated occupational choice data drawn from the best-fitting (IL) regime evaluated at its MLE parameter estimates for the whole sample from Table 4. Both the 'true' IL regime was estimated (as if one did not know where the data came from) and all other regimes. The results are reported in Table 7, bottom. Reassuringly, the true regime (IL) achieves the highest likelihood and the Vuong test is able to reject all counterfactual alternatives (including IL against SNL and BNL).
- The penultimate row in Table 7 reports the results of a run with an alternative (log-normal) specification for the ability distribution $\eta(\theta)$ for the whole sample. We see that, the results from the baseline (Table 5) remain robust — the saving regime is rejected by the Akaike test (and also by Vuong test for the lottery specifications) and the Vuong test cannot statistically distinguish between the borrowing and constrained insurance regimes.
- Another robustness run (Table 7, last row) restricts agents to be risk-neutral as in Aghion and Bolton (1997). I set $\gamma_1 = 0$ and estimate only the remaining parameters. In this specification the limited liability assumption (instead of the demand for insurance, in the baseline case of risk aversion) is what gives the moral hazard problem 'bite' in the constrained insurance regime since otherwise the moral hazard could be avoided by penalizing the agent sufficiently in the low-output state. The results from this run are again consistent with the baseline from Table 5.
- I also estimated a first-best (complete markets) version of the model by relaxing the assumption that entrepreneurial effort is unobservable to the bank (i.e., by removing the incentive constraint, ICC in the constrained insurance problem). This resulted in a worse fit between the model predictions and the

[33] Some issues pointing to this possibility such as large standard errors and 'flats' in the likelihood function were experienced in the estimation runs.

Table 7
Financial regime comparisons — robustness.

N	% business	Stratification	Test Z-statistics								
			Regimes without lotteries			Regimes with lotteries			Lottery vs no lottery		
			SNL vs BNL	SNL vs INL	BNL vs INL	SL vs BL	SL vs IL	BL vs IL	SNL vs. SL	BNL vs BL	INL vs IL
Regime comparisons allowing correlation between initial wealth and entrepreneurial ability											
2313	13.8%	Whole sample	0.069	−0.857	−0.922	−0.032	−1.347	−0.712	0.247	−0.060	0.192
1091	19.2%	Central region	−2.123**	−2.471**	−0.133	−2.826***	−2.356**	0.798	−0.230	−0.432	−0.188
1222	9.1%	Northeast region	0.377	−0.446	−1.047	−0.001	−0.794	−0.794	0.327	−0.199	−0.311
1157	12.6%	Wealth below median	−0.101	−1.029	−1.110	−0.871	−0.714#	0.158	0.134	−0.405	0.819
1156	15.1%	Wealth above median	−1.921*	−2.069**	−0.836	−1.667*	−2.567**	−0.618	−0.244	−0.391	−0.748
1927	12.8%	No formal credit	−4.032***	−4.240***	−0.819	−2.546**	−2.751***	−1.077	−3.334***	0.558	−0.032
386	19.2%	Formal credit	−0.986	−0.196	0.980	−2.326**	−0.511	1.651*	−0.012	−0.334	−1.117#
1388	16.1%	Any debt	−2.868***	−2.993***	−0.903	−1.685*	−1.873*	−0.572	−0.875	−1.310	−0.734
925	10.4%	No debt	−0.520	−1.286	−0.614#	−0.987	−0.470	0.430	−0.669	−0.667	0.717
Eight estimated parameters											
2313	13.8%	Whole sample	−1.376	−1.309	−0.198	0.167	−0.445	−0.363	−2.366**	−0.220	−0.248#
1091	19.2%	Central region	−0.893	−2.610**	−1.012	−1.775*	−1.946*	0.656	−1.508	−1.603	−0.319
1222	9.1%	Northeast region	−0.874	−1.040	−0.961	−0.315	−1.384	−1.052	0.257	−0.052	−0.887
1157	12.6%	Wealth below median	−0.252	0.139	0.139	−0.738	−1.220	0.551	0.298	−0.264	−0.416
1156	15.1%	Wealth above median	−0.362	−2.317**	−1.599	−1.947*#	−2.499**	−0.741#	0.174	−1.477	−0.182
1927	12.8%	No formal credit	−2.162**	−2.494**	−1.233	1.067	0.344	−1.137	−3.273***	−0.163	0.542
386	19.2%	Formal credit	−0.214	−2.162**	−1.995**	0.002	−0.103	−0.121	−0.570	−0.068	1.387
1388	16.1%	Any debt	−1.698*	−2.349**	−0.859	0.150	0.632#	0.443	−2.149**	−0.593	0.606
925	10.4%	No debt	−1.327	−2.190**	−1.073	−1.825*	−1.497	0.027	−0.072	−0.875	0.541
Additional robustness checks (whole sample)											
2313	13.1%	Using simulated data from IL	−0.918	−0.778	1.053	−2.491**	−3.424***	−1.680*	0.898	−0.769	−2.127**
2313	13.8%	Log-normal ability	−1.077	−1.092	−0.218	−2.848***	−2.957***	0.876	0.830	−1.978**	−0.432
2313	13.8%	Risk-neutrality	0.529	−3.329***	−3.575***	−6.586***	−7.568***	−1.537	6.379***	−0.614	−0.129

A positive value means that the regime listed first in the comparison provides better fit according to the Akaike (1973) criterion, a negative value means that the regime listed second provides best fit.

*** Significant at the 1% confidence level under the Vuong (1989) test.

** Significant at the 5% level.

* Significant at the 10% level.

\# Insignificant at the 5% confidence level according to the Clarke (2003) test.

data about the mapping from wealth to occupational choice, with the Akaike criterion rejecting the first-best regime against the information-constrained specification for all three baseline financial environments (SL, BL and IL). These results, available upon request, support the empirical relevance of financial constraints due to moral hazard as postulated in the theory section.

- As another consistency check, I have also done estimation runs with an alternative data on *young households* only, that is, households that might have become entrepreneurs only recently. These data are from the 1976 and 1996 rounds of the national Socio-economic Survey (SES) conducted by the Thai government (see Karaivanov, 2003 for the details). In 1976, when the financial sector in Thailand was much less developed than twenty years later, the saving only contract achieves better likelihood compared to the two other regimes and cannot be rejected by the Vuong test (all three regimes are tied). In contrast, with 1996 SES data the BL regime achieved the best fit, which is consistent with the financial deepening documented for Thailand (Gine and Townsend, 2004).
- Finally, I also ran the regime comparisons using an alternative test due to Clarke (2003). This test looks at the signs of the differences of the log-likelihoods at each data point for the two compared models. While the Vuong test can be interpreted as determining whether the mean likelihood ratio is statistically different from zero, the Clarke test checks whether the median likelihood ratio is statistically significant from zero. The test statistic is simply the number of positive individual log-likelihood differences between the two models and is distributed binomially with parameters the number of observations N and $p=.5$ under the null hypothesis. The baseline results remain robust using this test — only a single regime comparison is insignificant at the 5% level in Table 5 (BL vs. IL, 'any debt'). See also Table 7 for the robustness runs.

6. Conclusions

Financial constraints and the distribution of wealth and entrepreneurial ability are important factors influencing economic development. I analyzed and compared the predictions of exogenously and endogenously incomplete financial markets on the mapping between ex-ante wealth and occupational choice. Entrepreneurship is strongly affected by the type of financial constraints in the economy. Identifying the source of those constraints in actual data using structural methods as in this paper is important for at least two reasons. On the one hand it helps us select which known theoretical models are likely to be empirically relevant and which are not, while on the other hand it suggests directions for further improvements in modeling. The theory is taken to the data in its full structure and the data selects what theory is empirically plausible.

Empirically, I find that a savings only financial setting can be rejected in the Thai data in favor of settings featuring debt and/or constrained insurance. I also find evidence of differences by region and wealth in the regime of financial market imperfections fitting the data best — the savings only regime is strongly rejected by the Vuong test against the other two in the Central region closer to Bangkok, for households with wealth above the median, and for households who are debt holders but cannot be rejected for agents with wealth below the median and in the rural North-East.

These findings suggest possible directions for policy discussions and further research. Theory implies that, when agents are risk averse and subject to moral hazard, simple storage and debt (self-insurance) contracts are suboptimal relative to arrangements providing state-contingent partial insurance. Still, binding incentive constraints may prevent some low-wealth households obtain credit. As Paulson et al. (2006) suggest, one way of introducing contingencies in actual financial contracts include lenient repayment terms in bad states or setting up a more dispersed credit market with a variety of lenders. The fact that commercial banks in Thailand have been reluctant to seize collateral in the event of default and similar behavior is seen with loans from relatives is consistent with my findings since those two types of lenders are most prevalent in the Central region. In the Northeast, where credit seems more limited, a further investigation is needed whether this is due to supply or demand reasons, i.e., whether the cause is lack of collateral, less developed financial markets *per se*, or a vicious circle equilibrium involving both.

To the best of my knowledge the structural test on the role of randomization in occupational choice and financial intermediation I perform here is new to the literature. The results show that augmenting each of the three basic financial regimes with lotteries improves the fit with the data. This can be interpreted as indirect evidence for the importance of asset pooling mechanisms in developing countries. Certain functions performed by extended families could also lead to observationally equivalent results, e.g., if families can side-contract and direct resources toward the able but initially poor who are short of the business start-up threshold. Of course, there could also exist other ways to raise able but poor individual to entrepreneurial status — microfinance and/or subsidized loan interest rates are used in reality. However, unlike the pooling and randomization discussed here, these measures are in their nature redistributionary and not Pareto-improving for everyone.

The choice to resort to the simplest possible model with one-period financial contracts was imposed by data limitations and the computational complexity of structurally estimating dynamic models of occupational choice under asymmetric information and with history-dependent contracts. In Karaivanov and Townsend (2010) we are working to address this limitation by formulating and solving several prototypical models of dynamic financial constraints allowing for moral hazard, intertemporally linked contracts, and unobserved investment (see also Buera, 2009). These models allow (and require) that the researcher incorporate more data in the estimation such as consumption, investment, etc. to distinguish between financial regimes. In addition, to make them empirically operational one needs panel data and solving numerical problems pushing the limits of current technology.

There are also other directions in which this research can be improved and extended. The types of financial contracts in the model were exogenously given. Although the regimes were carefully chosen for their similarity to actual financial arrangements in the data, other types of contracts, e.g., with explicit collateral requirements and/or with limited enforcement also deserve attention and can be estimated using the methods developed here. Allowing for endogenous switching between contracts as those in Greenwood and Jovanovic (1990), or allowing agents to sign multiple contract types at the same time or interact with multiple intermediaries could broaden the analysis. Because of data and computational constraints, I used only wealth and occupational status data in the maximum likelihood estimation. Subject to availability, incorporating data on business income, wages or savings can enrich the current results. Further, the structural analysis here can be used to quantify the efficiency and welfare losses due to the credit market imperfections and also for policy evaluation and counterfactuals (see Townsend, 2010 ch. 9). Additional reduced-form or non-parametric estimation runs as in Paulson and Townsend (2004) and Paulson et al. (2006) would complement the structural results obtained here.

Appendix A. Proof of Proposition 1

Problem (Eq. (11)) is the problem of the bank contracting with an entrepreneur. The bank sets k, c_h and c_l and recommends an effort level z, which maximize the expected utility of the entrepreneur subject to two constraints: first, the recommended effort level must be optimal for the agent given k, c_h and c_l, constraint (ICC), and second, the bank must break even, constraint (BE1). The bank's problem contracting with a worker, Eq. (14) is similar, but there is no incentive compatibility constraint as effort is fully observable. Due to the concavity of the utility function, it is then optimal to set consumption equal across the two states, $c_l = c_h = c$.

The idea for the proof is based on Proposition 5 in Cole and Prescott (1995). We need to show that for any given wealth level, a, the contract (c, q, z, k) resulting from the solution of the allocation lottery program can be mapped into the solutions of the optimization problems (Eq. (11)) and (Eq. (14)) combined with an ex-ante lottery over wealth. The unique (because of concavity) solution to the allocation lottery program is the set of probabilities[34] $\{\pi^*(c, q, z, k|a) > 0\}$ satisfying the constraints in (6)–(9), whereas the solution to the wealth lottery problem can be written as $(c_j^*(a_1), z^*(a_1), k^*(a_1))$, $j = l, h$ and $(c_j^*(a_2), z^*(a_2), k^*(a_2))$, $j = l, h$ together with a probability $\mu^*(a)$ such that

$$a_1(1-\mu^*(a)) + a_2\mu^*(a) = a \tag{18}$$

and where c_j^*, k^* and z^* are the solutions to Eqs. (11) and (14). It is also clear that q in $\pi^*(c, q, z, k|a)$ can take only the values 0, θq_h and w_h due to technological feasibility.

Notice that, given our assumptions about the preferences (separability plus strict concavity) and the production function, the problems (Eq. (11)) and (Eq. (14)) have unique solutions in terms of c, z, k for any given value of a.Also, by the envelope theorem, the indirect utility functions $v^E(a)$ and $v^W(a)$ are concave, thus when wealth lotteries are used for convexification, the 'losers' and the 'winners' of the lottery would hold different occupations. Suppose that, without loss of generality, an agent with wealth a_2 would optimally choose to be an entrepreneur (i.e. $v^E(a_2) > v^W(a_2)$), whereas an agent with wealth a_1 would optimally choose subsistence work. Let us denote $\Pi_1 \equiv \{\pi^*(c, q, z, k|a) \mid k = 0\}$, to be the set of contracts under which the agent is a worker and $\Pi_2 \equiv \{\pi^*(c, q, z, k|a) \mid k > 0\}$, to be the set of contracts under which the agent would be an entrepreneur.[35]

Suppose that there exist two optimal contracts $\pi_1^*(c_1, q_1, z_1, k_1)$ and $\pi_2^*(c_2, q_2, z_2, k_2)$ in Π_2, such that their corresponding effort and investment assignments are not the same, i.e. $(z_1, k_1) \neq (z_2, k_2)$. Since u and p are concave in z and k, this would imply that a linear combination of the two would achieve higher utility for the entrepreneur and still be feasible which is a contradiction. Thus it must be the case that $z_1 = z_2 = z^1$ and $k_1 = k_2 = k^1$ implying that there are only two elements in Π_2, $\pi_{21}^*(c_h^1, \theta q_h, z^1, k^1)$ and $\pi_{22}^*(c_l^1, 0, z^1, k^1)$. Similarly, there are only two elements in Π_1: $\pi_{11}^*(c_h^2, w_h, z^2, 0)$and $\pi_{12}^*(c_l^2, 0, z^2, 0)$.

Now we only have to show that $(c_j^i, z^i, k^i) = (c_j^*(a_i), z^*(a_i), k^*(a_i))$ for $j = l, h$, $i = 1,2$ to finish the proof. Define $\hat{\pi}_{11} \equiv (1-\mu^*(a))p(w_h|z^*(a_1), 0)$, $\hat{\pi}_{12} \equiv (1-\mu^*(a))p(0|z^*(a_1), 0)$, $\hat{\pi}_{21} \equiv \mu^*(a)p(\theta q_h|z^*(a_2), k^*(a_2))$, and $\hat{\pi}_{22} \equiv \mu^*(a)p(0|z^*(a_2), k^*(a_2))$. It can be seen immediately from (BE1), (BE2) and (ICC) together with Eq. (18) that the vector $(\hat{\pi}_{11}, \hat{\pi}_{12}, \hat{\pi}_{21}, \hat{\pi}_{22})$ satisfies Eqs. (7) and (8). It also satisfies Eqs. (6) and (9) by construction, thus it is feasible for the linear program (Eq. (5)). Conversely, Eq. (6) implies that $\frac{\pi_{11}^*}{p(w_h|z^2,k^2)} = \frac{\pi_{12}^*}{p(0|z^2,k^2)} \equiv \mu_1$ and $\frac{\pi_{21}^*}{p(\theta q_h|z^1,k^1)} = \frac{\pi_{22}^*}{p(0|z^1,k^1)} \equiv \mu_2$.Then from Eq. (9) we have that $\mu_1 + \mu_2 = 1$, i.e. it is clear that (z^i, k^i), the implied c_j^i, and μ_1 and $1-\mu_1$ satisfy the constraints of Eqs. (11) and (14) together with Eq. (18) and thus are feasible for the wealth lottery problem. Finally, suppose that $(c_j^*(a_i), z^*(a_i), k^*(a_i))$ together with μ_1 and $1-\mu_1$ are not maximizing for the wealth lottery problem, i.e., some agent can achieve higher utility. But then the mapping of $(c_j^*(a_i), z^*(a_i), k^*(a_i))$ and μ^* into the π-contracts described above would produce an allocation in which all

[34] I will refer to this set as the set of optimal contracts.

[35] It can never be optimal to assign $k = 0$ for an entrepreneur as this implies zero output at any effort level, whereas if the agent were assigned to be a worker at the same effort level, she would produce positive output. Thus all agents assigned entrepreneurship will have $k > 0$.

agents are at least as well off as with (π^*_{11}, π^*_{12}, π^*_{21}, π^*_{22}) which is a contradiction.

Appendix B. Solution methods

Using Proposition 1, to solve for the constrained optimal insurance contract one needs to solve problems (Eq. (11)) and (Eq. (14)) and compute the appropriate wealth lottery. Mathematically, this is equivalent to finding the convex hull of the function $v(a)$. One possible strategy is to use the linear programming approach of Prescott and Townsend (1984) separately for each occupation but this has all disadvantages already discussed. Instead, I solve the problems in their non-linear form as written above. The worker's problem (Eq. (14)) is a standard non-linear maximization program and can be solved by conventional optimization methods. To solve the entrepreneur's problem Eq. (11), however, we need to transform the incentive compatibility constraint (ICC) into a more manageable form. A standard way to do this is to replace it by the first order condition with respect to effort. This is known as the ‘first order approach’. As demonstrated by Rogerson (1985), this approach is by no means universally valid and requires some restrictive properties to be satisfied by the probability function mapping effort into output. The next result shows that the first order approach is valid under our assumptions, i.e. the solution obtained by replacing the maximization problem in (ICC) with its first order condition is indeed a maximum of the objective function of Eq. (11). Notice that without Proposition 1 we would not have been able to perform the decomposition of the bank's problem and hence we would not have been able to use the first order approach for the entrepreneurs.

Proposition 2. (Validity of the first order approach)

The production function $p^E(q|z, k)$ satisfies the monotone likelihood ratio property (MLRP) and the convexity of the distribution function condition (CDFC) implying that the first order approach is valid.

Proof. Let me first verify MLRP, i.e., show that $\frac{\partial p^E(q|z,k)}{\partial z}\frac{1}{p^E(q|z,k)}$ is non-decreasing in q. Since there are only two possible output levels, I need to show that

$$\frac{\partial\left(1-\frac{k^\alpha z^{1-\alpha}}{1+k^\alpha z^{1-\alpha}}\right)}{\partial z}\frac{1}{1-\frac{k^\alpha z^{1-\alpha}}{1+k^\alpha z^{1-\alpha}}}\le\frac{\partial\left(\frac{k^\alpha z^{1-\alpha}}{1+k^\alpha z^{1-\alpha}}\right)}{\partial z}\frac{1}{\frac{k^\alpha z^{1-\alpha}}{1+k^\alpha z^{1-\alpha}}}$$

which is obviously true as the left hand side is negative and the right hand side is positive. Next, verifying the CDFC is equivalent to showing that $\frac{\partial^2 p^E(q_l|z,k)}{\partial z^2}$ and $\frac{\partial^2 p^E(q_l|z,k)}{\partial z^2}+\frac{\partial^2 p^E(q_h|z,k)}{\partial z^2}$ are non-negative, where q_l and q_h are the two possible output levels with $q_l<q_h$.The first derivative is equivalent to

$$\frac{\partial\left(-\frac{(1-\alpha)k^\alpha z^{-\alpha}}{(1+k^\alpha z^{1-\alpha})^2}\right)}{\partial z}=\frac{\alpha(1-\alpha)k^\alpha z^{-\alpha-1}\left(1+k^\alpha z^{1-\alpha}\right)+2(1-\alpha)^2k^{2\alpha}z^{-2\alpha}}{(1+k^\alpha z^{1-\alpha})^3}>0.$$

We also have:

$$\frac{\partial^2 p^E(q_h|z,k)}{\partial z^2}=\frac{\partial\left(\frac{(1-\alpha)k^\alpha z^{-\alpha}}{(1+k^\alpha z^{1-\alpha})^2}\right)}{\partial z}=-\frac{\partial^2 p^E(q_l|z,k)}{\partial z^2}$$

thus the second expression is non-negative as well. Given this, Proposition 1 in Rogerson (1985) implies that the first order approach is valid in our setting.

The proof of the sufficiency of the MLRP and CDFC for the validity of the first order approach is in Rogerson (1985). In general, in a setting with more than two output levels, the two conditions become more restrictive but can still be satisfied by imposing appropriate conditions on the production function. Importantly, the numerical solution method proposed in the paper *do not* necessarily require the use of the first order approach since a significant improvement in computational speed and memory usage is achieved already by decomposing the problem into the two sub-problems, one per occupation.

Having shown that the first order approach is valid, we can replace the (ICC) by the first order condition $\frac{\partial u^*}{\partial z}=0$ which is a non-linear equality constraint in z, c and k and use standard non-linear optimization methods to solve problem (11). The only remaining issue is computing the wealth lottery, which is equivalent to convexifying $v(a)=max\{v^E(a),\ v^W(a)\}$ by taking its upper convex hull, $v^C(a)$. This step is performed by choosing a dense discrete grid on wealth, $\{a_j\}_{j=1}^n$, computing the value of $v(a)$ at the grid points by solving problems (Eq. (11)) and (Eq. (14)), and then computing the upper convex hull[36] of the set of points with coordinates $(a_j, v(a_j))$. After the hull is computed, we can evaluate it at any wealth level by using a spline approximation and back out the respective (randomized) optimal contract.

The proposed method of solving for the optimal insurance contract has the following advantages. First, no grids are used in the optimization, which reduces the memory and computational time requirements. The relative performance in terms of computational speed is about ten to twenty times higher for the two-stage approach proposed here compared to the linear programming approach using standard non-commercial maximization routines and average grid sizes. Second, using non-linear methods improves the solution precision as the optimization is done on continuous as opposed to discrete sets of values. Third, lotteries are used only and exactly when they are needed, in contrast to the allocation lottery formulation in which grid lotteries can affect the results. Finally, the results of the optimization do not come out in the form of the ‘artificial’ objects $\pi(c, q, z, k)$ which are somewhat hard to interpret from an economic point of view. Instead, we directly obtain the assigned transfer, investment and effort levels. A potential disadvantage of the method is, however, its reliance on more restrictive assumptions compared to the linear programming approach which could limit its applicability in some particular settings.

Appendix C. Likelihood maximization

The numerical procedure used to solve the likelihood maximization problem involves several steps. First, for any parameters ϕ, and any given values for θ and a, I need to solve the relevant optimization problem and compute the predicted probability of being entrepreneur, $h(a|\phi,\theta)$. In this step, I use extensively the results of Propositions 1 and 2 to optimize the numerical solution methods. Second, since θ is unobserved by the econometrician, I need to compute the expected value of $h(a|\phi,\ \theta)$ integrating over θ, that is, $h^e(a|\phi)\equiv\int_{\kappa}^{1+\kappa} h(a|\phi,\theta)\eta(\theta)d\theta$. This is done using Gauss-Legendre quadrature with five nodes (Judd, 1998). This numerical integration method was chosen to minimize the number of function evaluations and because of its asymptotic properties. Third, because of computation time constraints, I cannot afford to compute $h^e(a|\phi)$ at all data points for wealth (2313 in the whole sample), so I construct a 20-point non-uniformly spaced grid on [0,1] and compute $h^e(a|\phi)$ only at the grid points.[37] To obtain the value of h^e for all wealth points in the data as needed in the estimation, I then use cubic spline interpolation to generate the probability of being entrepreneur predicted by the model for any given wealth level a, $H(a|\phi)$.This procedure is followed for each regime.

[36] The convex hull computation method is based on the Quickhull algorithm (Barber et al., 1996).

[37] The unequal spacing between the grid points is chosen because the wealth data is heavily right-skewed.

A common practical problem with likelihood functions arising in the structural estimation of discrete choice models where the likelihood has no analytic representation and is derived using equilibrium outcomes can be multiple local extrema and/or flat areas in the likelihood. This presents difficulties using standard optimization methods based on derivatives (e.g., versions of the Newton method). To avoid these problems and to be confident that the parameter estimates I obtain correspond to a global maximum, I use a multi-stage computational algorithm to maximize the likelihood. In the first stage a deterministic grid search is conducted over the estimated parameters. The second stage uses a genetic optimization algorithm (Houck et al., 1995). I initialize the algorithm using as initial population the fifty best candidates for maxima from the grid search plus fifty randomly generated parameter vectors.

In brief, the idea behind the genetic algorithm is as follows. Given an initial 'population', consisting here of a set of parameter vectors and their corresponding likelihoods ('fitnesses'), the algorithm searches over the parameter space simulating evolution, i.e., survival of the 'fittest' parameter vector. A major advantage of the genetic algorithm over other global search methods (e.g., the Nelder-Mead simplex algorithm) is that it is not deterministic and hence is unlikely to become stuck at a local maximum. The currently best parameter vectors have the highest chance of survival but inferior ones could also survive enabling the search to continue in several promising areas of the parameter space simultaneously. During each algorithm step a new "generation" of parameter vectors is created from the previous generation using probabilistic selection based on their likelihood. The selected parameter vectors are then subjected to genetic operators which implement the search function of the algorithm. Two basic types of operators are used, *crossover* (when two new vectors are produced from two old ones, e.g. using a linear combination) and *mutation* (when a single parameter vector is changed). The algorithm stops after a pre-specified number of generations (fifty here) and/or when the current population is homogeneous enough.[38]

As a third and final stage of the likelihood maximization procedure I run a Nelder-Mead simplex search with stricter tolerance around the best parameter vector obtained from the genetic algorithm stage to ensure that all local gains from optimization are exploited. The standard errors for the MLE estimates are computed using bootstrapping, drawing with replacement from the sample.

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[38] For more formal and detailed description of genetic algorithms see Davis (1991).