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ABSTRACT

This paper examines firm ownership structures in competitive general equilibrium by introducing a model where ownership rights emerge endogenously rather than being assumed. By embedding the property rights theory of the firm into general equilibrium analysis, the model demonstrates how market forces determine both initial firm formation by entrepreneurs and subsequent trading of ownership rights. The key finding is that, in equilibrium, firms are created by managers who have long-term importance to performance, but these founder-managers then sell ownership to outside investors. This pattern emerges because managers can capture value through both the sale price and their ongoing employment relationship, while outside owners can only benefit through ownership. The model thus provides a novel theoretical foundation for observed patterns of entrepreneurial exit and reconciles competing approaches to firm ownership in general equilibrium theory. Additionally, it identifies a distinct economic definition of an entrepreneur as an agent whose human capital is valuable for firms even when they do not remain long-term owners. The framework generates insights into firm formation, ownership dynamics, and the nature of entrepreneurship while maintaining the core structure of competitive general equilibrium analysis.

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1 Introduction

Firm ownership structures in modern economies are diverse. In the United States, of the 8 million or so firms, 4,500 are public companies, but these companies account for around 23 percent of private employment. This mirrors long-standing results on the diversity of firm ownership (Hansmann, 2000). Given this, it is somewhat surprising that the foundational model of economics – competitive general equilibrium theory – offers no insights into that structure. The goal here is to demonstrate that with some relatively small amendments, rich insights are possible with implications that mirror observed patterns of firm ownership. In the process, the economic nature of entrepreneurship can be addressed and identified in ways not possible from other theoretical traditions.

The firm holds an unusual position in general equilibrium theory. While many other analyses of firms treat it as an agent or composed of other agents, the general equilibrium firm is a mere conduit for a production technology. It plays no distinct economic role, and if it obtains non-zero profits, the only modelling choice is who the recipients of those profits are. This implies that the theory offers no predictions regarding firms and their ownership. Each is an assumed artifact of underlying model assumptions.[1]

This paper seeks to redress this omission by making the outcome of who owns each firm endogenous. The ownership of firms has been a thoroughly explored topic in microeconomics, but its integration into general equilibrium has been limited.[2] This matters because, as will be noted, firm ownership is driven by outcomes in related markets, particularly the markets for labour and capital.

Here, the property rights theory of the firm is embedded in a general equilibrium setting. Formulated by Grossman and Hart (1986) and Hart and Moore (1990), the property rights theory defines a firm based on the ownership of non-human assets such as capital goods, equipment, buildings, land and intellectual property. That firm then employs people to work with those assets to produce output. The firm owners have residual control rights over access to assets (i.e., they can withdraw them from use by others) and residual income rights to output generated from production (not covered by other contractual commitments). Such control does not exist over people whose human capital is inalienable and, thus, must be induced to work at any given point in time. It is this distinction with non-human assets that

[1] Jacques Dreze (1985) explored this issue when he wrote, "The firm fits into general equilibrium theory as a balloon fits into an envelope flattened out! Try with a blown-up balloon: the envelope may tear, or fly away at best, it will be hard to seal and impossible to mail... . Instead, burst the balloon flat, and everything becomes easy. Similarly with the firm and general equilibrium."

[2] Some research has integrated contracting and hold-up problems into macroeconomics (Caballero and Hammour (1998) and Caballero (2007)), and international trade theory (Antràs (2003) and Grossman and Helpman (2005)) and industrial organisation (Azar and Vives, 2021).

drives the definition of the firm: "[N]on-human assets are an important part of any firm; they are the glue that holds the firm together." (Hart, 2017)

The property rights theory forms predictions regarding firm ownership structure by considering the efficient allocation of control rights over assets to agents. It does not consider the equilibrium allocation of assets to potential owners that would arise in a market environment. This theory provides, therefore, a structure under which to consider asset ownership and when and how it might matter, but not an analysis of how such assets are created and who ultimately controls them. The present paper fills this gap by modelling asset creation as being driven by the decentralised (optimising) choices of agents and ultimate ownership as being determined by the forces of supply and demand in asset markets jointly determined as an equilibrium in other related markets, in particular, labour markets. Thus, it embeds this theory in general equilibrium theory by considering agent choices taking prices in relevant markets as given.

To accommodate the property rights theory of the firm into general equilibrium, this paper makes one important departure from the latter. It is assumed that binding contracts over labour cannot be written; that is, employment is fundamentally 'at-will,' and workers cannot be compelled to provide services.[3] If it were the case that there were always close substitutes for workers, the nonbinding nature of labour contracts would not necessarily have a distinct role over contracts for other services. However, the starting point here will be that workers in a firm have specific skills that are difficult (or, in the case of the baseline model, impossible) to replace. As Stole and Zwiebel (1996a) and Stole and Zwiebel (1996b) demonstrate, in this case, stable (or renegotiation-proof) wage outcomes for a firm are determined by the equilibrium of a bargaining game, namely, the Shapley value. In integrating this into general equilibrium theory, this allocation of value is assumed.[4]

1.1 Contributions of the Paper

The theory and results in this paper offer three distinct contributions. First, by placing it in a general equilibrium setting, the model of Hart and Moore (1990) is enriched to include asset creation and trading. Second, a special role for the entrepreneur is identified within the context of general equilibrium theory. Finally, the long-standing schism regarding the

[3]This is a well-recognised feature of labour contracts; see Posner (2014) for a discussion.

[4]Here, it is assumed that intra-firm bargaining outcomes are given by the Shapley value between workers and capital owners as in Hart and Moore (1990). Stole and Zwiebel (1996a) developed an axiomatic approach that derived this outcome, which was developed in a dynamic setting by Wolinsky (2000). See Raith (2021) for a recent exploration of this contractual environment, which often relies on relational contracts when spot contracts are not available. Brügemann et al. (2019) and de Fontenay and Gans (2014) provide non-cooperative games that generate the Shapley value outcome in this environment. For an alternative perspective on cooperative game theory outcomes in a firm context, see Aoki (1980) and Aoki (1984).

treatment of firm ownership in Arrow and Debreu (1954) versus McKenzie (1959) is resolved. Each is briefly explained in turn.

The model here shows what happens when the approach of Hart and Moore (1990) is embedded in a general equilibrium model.[5] In contrast to that literature, while it is assumed here that capital investment is non-contractible (that is, there is no firm to negotiate with until it is formed) and wages in firms are non-binding, the baseline model does not consider any other contractual incompleteness (i.e., worker effort).[6] Nonetheless, it is demonstrated that ownership matters. In equilibrium, assets can be traded amongst agents, and it is shown that agents outside the firm (e.g., households) will end up acquiring ownership over those inside the firm. This arises because the former only appropriate the firm value if they are owners, while the latter will appropriate value as non-owners, which reduces their willingness to pay for ownership. This is the same effect identified by Gans (2005) for the standard Hart and Moore (1990) environment with incomplete contracts and no general equilibrium. The nuance here is that labour market effects reinforce these effects and also imply that they arise even once the usual targets of contractual incompleteness are absent.

While the eventual equilibrium in the economy, in contrast to a central prediction of Hart and Moore (1990), involves firms being owned by outsiders, it is demonstrated that these are not the agents who invest and create the assets in the first place. Those are skilled workers – which we term managers or entrepreneurs – who have long-term importance to firm value.[7] Such agents have a stronger incentive to create assets precisely because firm creation provides them with an ongoing role in the firm they founded, but also that they can trade assets ex-post to appropriate the returns outsiders would obtain. Indeed, it is shown that such ex-post trading provides a greater incentive to build firms than would arise in a typical Hart and Moore (1990) environment. In this regard, this paper endogenously provides a distinct entrepreneurial role in competitive economies as single-agent founders of firms while at the same time explaining how entrepreneurs choose to relinquish ownership and control.

It is useful to emphasise that the role for an entrepreneur, or an agent that performs the entrepreneurial function, is distinct from others identified in the literature. In terms of general equilibrium theory, the work of Kihlstrom and Laffont (1979) was the first to

[5]There is some other work that has integrated aspects of bargaining and internal firm contracting into general equilibrium theory; for example, Zame (2007) and Ellickson et al. (2006). These, however, do not endogenise firm ownership.

[6]It, therefore, avoids the concerns about the foundations for contractual incompleteness that have challenged theorists in developing the property rights theory of the firm; see Hart (2017).

[7]In this regard, the model presented here addresses, head-on, the famous critique by Baumol (1968) that "[t]he theoretical firm is entrepreneurless – the Prince of Denmark has been expunged from the discussion of *Hamlet*."

consider which agents become entrepreneurs and identified those who were less risk averse as being willing to bear the uncertainty associated with firm formation.[8] The model here does not have uncertainty and so is a complement to this work, although it shares with it that entrepreneurs are drawn from the pool of workers. However, here: *a* ***firm-founding entrepreneur*** *is an agent drawn from the set of agents who are of long-term importance to the firm.* Thus, who becomes an entrepreneur is intimately tied to their role in production rather than their individual characteristics.[9] Indeed, anecdotally, the founders of the largest technology firms (e.g., IBM, Intel, Microsoft, Apple (sort of), TSMC, Broadcom, Amazon, Google, Nvidia, Tesla, Netflix and Facebook (also sort of)) continued to be managed by (or employ) their founders even long after the sale of majority stakes to outside investments.

The issue of the ownership of firms was front and centre as economists set out to formally prove the existence of a general equilibrium in a competitive economy. Arrow and Debreu (1954), who wanted the theory to accommodate production technologies that included both constant and diminishing returns, realised that firms would earn quasi-rents and that those profits would have to be allocated to complete the model. They chose to allocate firm ownership to households (with arbitrary shareholdings) and to assume that the set of firms in the economy was itself given and that from that set, a subset of firms would be active in equilibrium if they employed a strictly positive quantity of some input. This contrasted with the parallel approach of McKenzie (1959), who argued for constant returns to scale, which involved no profits under competition and, therefore, no need to distribute profits. In this regard, entrepreneurs would be another input into production, and any rents they received would equate to what might be commonly thought of as entrepreneurial profits. In other words, Arrow and Debreu (1954) assumed that firms were outside owned, while McKenzie (1954) effectively assumed they were owned by a specific factor.

At the heart of the choice between these approaches to firm ownership was whether entrepreneurs, as a distinct factor, were scarce or not. As Arrow (1971) wrote:

> In more modern language, the production possibility set of the typical firm displays an initial tendency toward increasing returns followed at higher scales by decreasing returns. The first phase is explained by indivisibilities, the second by the decreasing ability of the entrepreneur to control the firm. As one may put it, entrepreneurship should also be regarded as an input to the firm; then, after the initial phase at least, the firm would have constant returns to all inputs

[8]That said, even this intuitive conclusion was subject to nuances as outlined in their later work; Kihlstrom and Laffont (1982) and Kihlstrom and Laffont (2002).

[9]This notion is assumed in other models including Romer (1990) where the supply of firms is driven by the supply of ideas and Aghion and Tirole (1994) and Gans and Stern (2000) where independent entrepreneurs enter based on industry characteristics and intellectual property protection.

> (including entrepreneurship), but, since by definition the firm has only one entrepreneur, there are diminishing returns to all other factors. (The indivisibility of the entrepreneur is sometimes invoked to explain the initial phase also, though of course there are typically also indivisibilities of a more definitely technological variety.) The assumption of free entry implies that the supply of entrepreneurship in the economy is infinite, or, more precisely that it is sufficiently large that its demand price will fall to zero at a point at which supply still exceeds demand.
>
> The exact relation of this model of the firm to a full general equilibrium model has never been explored; in particular, the notion of an infinite supply of entrepreneurship is no more reasonable than that of an infinite supply of anything else. Arrow (1971), p.69.

Arrow's objection, therefore, was that entrepreneurs were implicitly not scarce in McKenzie's model. The present paper takes this critique seriously. First, entrepreneurs are assumed to come from the pool of agents, which itself is scarce. Second, once a firm is formed, entrepreneurs themselves are scarce. Finally, in contrast to both approaches to firm ownership, this paper makes ownership endogenous and, thus, is able to generate a prediction as to when ownership might arise with an owner-manager (or entrepreneur) as opposed to outsiders (or households). As already discussed, this resolution turns out to be nuanced with both types of ownership naturally arising in different 'stages' of the firm's lifecycle. Doing this is important because, as Arrow noted, the important role of an entrepreneur is in "overcoming disequilibria. When profit rates were unequal, profit-hungry entrepreneurs moved quickly, with the end result of eliminating their functions." (Arrow (1971), p.68) Thus, the model here provides a foundation, not explored in this paper, for incorporating disequilibrium into general equilibrium theory.[10]

1.2 Outline of the Paper

The paper proceeds as follows. The next section provides a description of the model. It is a specific general equilibrium environment with joint production opportunities and a self-production sector, among which a fixed pool of labour makes its participation decisions. As a benchmark, the equilibrium outcomes when ownership is exogenous – both manager-owned and outside-owned – are characterised. Section 3 then provides the main results of the paper when firm ownership is endogenous, allowing both asset creation and ex post asset trading

[10] Arrow and Debreu (1954) was not without its own issues with regard to firm ownership as cogently explored by Ellerman (2021). The contention here is that this paper, by endogenising ownership ,answers Ellerman's concerns as well.

to take place amongst agents of different types. Section 4 then extends the model to the case of incomplete contracts as in the full Hart and Moore (1990) context and shows that this creates a greater diversity of possible firm ownership equilibrium outcomes than outside ownership. Section 5 then engages in an extensive revisit of the assumptions of the baseline model to examine their robustness to various changes and finds the results are unchanged. The final section concludes and offers directions for future research.

2 Description of the Model

The economy is comprised of a unit mass of agents who all have linear utility in consuming a single good. That good is the numeraire, with its price set equal to 1. Another alternative use for that good is as a capital asset that can be used as an input into its production.

There are two production sectors in the economy: a self-production sector and a joint-production sector. Let l be aggregate employment in self-production and $L = 1 - l$ be aggregate employment in joint-production.[11] The output of the self-production sector is given by a non-decreasing and concave production function, $f(l)$.[12] For convenience, it will be assumed that:

$$f(l) = \frac{1}{1+\frac{1}{\eta}}\left(1-(1-l)^{1+\frac{1}{\eta}}\right)$$

with $\eta > 0$ (a parameter that will represent the wage elasticity of joint-production labour supply). Payments for labour in this sector, which are denoted by w, are equal to their marginal product:

$$w = f'(l)$$

This sets the supply function for labour to the joint-production sector as:

$$L = w^{\eta}$$

which has a constant supply elasticity of $\frac{\partial L}{\partial w}\frac{w}{L} = \eta$.

In the joint-production sector, if a capital asset (comprising one unit of the good) is combined with a skilled worker and a skilled manager (to manage the worker and asset), y units of the good are produced. It is assumed that the worker and manager have skills

[11] Here we are following the setup of Caballero and Hammour (1998). There are some important differences. They actually assume three production sectors with different factor types that are combined in joint production and also operate in distinct self-production (or autarky) sectors. Here, labour will be drawn to joint production from a single self-production sector. Nonetheless, Appendix B shows that the main results of the paper apply in the usual, more 'general,' general equilibrium environments.

[12] The concavity of $f(.)$ implies that another factor exists that is supply-constrained in the self-production sector. This may be land or some other competitively supplied resource.

specific to each other and the assets of the firm, but if no joint production takes place, each agent can return to the self-production sector. The asset is also specific to the two skilled agents and, thus, has no value if no joint production takes place. Thus, joint production involves fixed coefficients and constant returns to scale.

Firms that engage in joint production are not given and are formed endogenously when capital investment takes place, and are disbanded if it is not used in production. It will be efficient for a firm to form if its output exceeds its costs:

$$y \geq 1 + 2w$$

Here, it will be assumed that $y \in (1, 3]$ as this is the interesting case.[13] Note that if the efficient number of firms is formed, then $w^* = \frac{1}{2}(y-1)$. In this case, at the resulting efficient allocation of labour to joint production, L^*, the number of firms formed is $N^* = \frac{1}{2}L^* = (\frac{1}{2})^{1+\eta}(y-1)^{\eta}$. Aggregate consumption is, therefore:

$$C^* = N^*y - N^* + f(1 - L^*) = \tfrac{1}{1+\eta}\left(\eta + \left(\tfrac{1}{2}(y-1)\right)^{1+\eta}\right)$$

This provides a social welfare benchmark for the equilibrium analysis that follows.

2.1 Timeline

The timeline for agent decisions and payoffs is as follows:

1. (Firm Formation) Capital invested by either managers (M) or outsiders (O) for joint production, and firms are formed.

2. (Specificity) Workers choose to acquire skills specific to capital at the firm level.

3. (Asset Trading) Ex post asset trading resulting in the final resolution of ownership structure in terms of manager or outside ownership, i.e., $s \in \{M, O\}$.

4. (Negotiations) Skilled workers and firms negotiate over wages, w_s, in joint production with outcomes determined by the Shapley value.

5. (Production) Income is distributed, and output and consumption are generated.

[13] If $y \leq 1$, it will not be efficient for any joint production to take place while, in the variants explored below, if $y > 3$, no self-production will take place and there will be a corner solution. However, a corner solution will not alter any of the results presented below; it is just ruled out here to keep computations simple going forward.

We will look for a rational expectations equilibrium outcome that generates equilibrium income for each agent, the number of firms formed, the ownership structure of those firms and aggregate output and consumption. That is,

Definition 1 (Rational Expectations Equilibrium) *A* rational expectations equilibrium *of this economy is a specification*

$$\Big\{w,\, l,\, L,\, N,\, \{s_i\}_{i=1}^{N},\, \{w_s\}_{s\in\{M,O\}},\, (\textit{agent-sector assignments}),\, (\textit{ownership-trading rule})\Big\}$$

such that (i) the labour market clears; (ii) initial ownership assignments, s_i. for each firm, i, ownership assignments satisfy individual rationality of investors/managers at the time of investment; (iii) an agent acquires firm-specific skills if this satisfies individual rationality; (iv) for the final asset allocation, there is no price exists at which both buyer and seller would wish to trade, given the subsequent bargaining outcome; (v) in each firm i, given final ownership $s_i \in \{M, O\}$, the worker(s)' wage w_{s_i} and the residual profit π_{s_i} to the owner satisfy w_{s_i} = Shapley-value payoff to the worker(s), $\pi_{s_i} = y -$ workers' wages; and (vi) the final good is numéraire with unit price.

Any allocation of (i) which agents invest in capital, (ii) which agents become skilled workers/managers, (iii) how ownership is reassigned ex post, (iv) the resulting Shapley wages, and (v) final consumption that satisfies all the above conditions constitutes a rational expectations equilibrium.

It is worthwhile discussing the assumptions underlying each stage in the timeline. The first stage is the investment of capital and the formation of a firm, recalling that a unit of capital is sufficient to allow a firm to engage in joint production so long as one worker of each type can be employed. That investment can be undertaken by any agent, but we will make a distinction between investments undertaken by the agent who will become the eventual manager of the firm and those undertaken by any other agent whom we refer to as outsiders. In the former case, we have ownership by a factor of production, while in the latter case, ownership is by households. In each case, the owner will be entitled to the profits, if any, generated by the firm.

The second stage involves the choice of agents to move into the joint production sector by choosing a firm and acquiring skills specific to that firm's capital. It is easy to see that, in equilibrium, only one skilled worker and one skilled manager make that choice for each firm.[14] As will be discussed below, this creates a meaningful hold-up issue for the capital

[14]This could be explicitly modelled by assuming that agents face an infinitesimal but positive sunk cost of skill acquisition. This would imply that in equilibrium, no more than one agent acquired the skills of a worker or a manager specific to a firm.

owners of any firm, as such workers cannot be replaced ex post.[15]

In the third stage, the initial capital owners, who have already sunk investment costs, have an opportunity to sell the capital assets to other agents. In particular, an outside owner can sell to a manager, while a manager can sell to an outside owner. For simplicity, it is assumed that the skilled worker cannot acquire ownership.[16] Thus, this stage represents the critical way in which firm ownership is considered endogenous in this setup.

Negotiations take place between the two agents and the outside owner or between the skilled worker and the manager, as the case may be. Each party is assumed to receive their Shapley value through these negotiations. This represents a clear departure from the neoclassical model of general equilibrium, where long-term labour contracts are possible. Here, by contrast, employment is assumed to be 'at-will,' meaning that workers are free to leave the firm. The threat of that, in addition to their irreplaceability, justifies the use of the Shapley value as a model of the outcomes of negotiations for at-will employment. This is standard in the property rights theory of the firm (Hart and Moore, 1990) and is justified more thoroughly by (Stole and Zwiebel, 1996a).[17]

The final stage involves production taking place and income, in the form of wage payments and profits, being distributed to agents to be used to purchase and consume the good produced.

2.2 Equilibrium with Exogenous Ownership

To provide a point of comparison with the endogenous ownership outcomes, it is useful to describe what would happen if ownership were exogenous, meaning that only certain ownership structures were permitted as per assumptions that are standard in general equilibrium models with production.

First, consider M-ownership. Any agent can choose to become a skilled manager, invest capital and form a firm that they eventually manage. In subsequent negotiations with a skilled worker, the wages paid to that worker will be $\frac{1}{2}y$, and the (gross) profit to the manager will be $\frac{1}{2}y$. This is because each has an outside option of returning to self-production. Given

[15]In extensions to the model below, this irreplaceability assumption is relaxed.

[16]This simplifies the analysis, but nothing would change if this assumption were relaxed so long as the skilled agents in a firm could not coordinate asset allocation to become joint owners and also if there were sufficient numbers of skilled agents in a firm; see Gans (2005). Gans (2006) shows that when all workers can bid for the asset, outside ownership still results as the eventual equilibrium outcome.

[17]For a non-cooperative justification of the Shapley value in this context, see de Fontenay and Gans (2014) and also Brügemann et al. (2019).

this, an agent will form an M-owned firm if:

$$\frac{1}{2}y - 1 \geq w \Leftrightarrow y \geq 2 + 2w$$

The threshold for firm formation is higher than the efficiency level, so too few firms will be formed in equilibrium. Nonetheless, in equilibrium, this inequality will bind, and so equilibrium wages will be $w_M = \frac{1}{2}(y-2)$. This results in consumption of:

$$C_M = \frac{1}{2}(y-1)\left(\frac{y-2}{2}\right)^{\eta} + \frac{\eta}{1+\eta}\left(1 - \left(\frac{y-2}{2}\right)^{1+\eta}\right)$$

This demonstrates that an equilibrium under M-ownership that results in some joint production requires that $y > 2$.

Now consider O-ownership. In this case, no agent who works in the joint production of a specific firm can own the capital of that firm.[18] The Shapley value allocations of surplus from the resulting negotiations will be $\frac{1}{3}(y+w)$ to the skilled worker and manager and $\frac{1}{3}(y-2w)$ to the outside capital owner. Given this, an agent (or agents) will form an O-owned firm if:

$$\frac{1}{3}(y-2w) - 1 \geq 0 \Leftrightarrow y \geq 3 + 2w$$

This threshold for firm formation is even higher than that for an M-owned firm. Again, in equilibrium, this inequality will bind, resulting in wages of $w_O = \frac{1}{2}(y-3)$ and consumption of:

$$C_O = \frac{1}{2}(y-1)\left(\frac{y-3}{2}\right)^{\eta} + \frac{\eta}{1+\eta}\left(1 - \left(\frac{y-3}{2}\right)^{1+\eta}\right)$$

This demonstrates that an equilibrium under O-ownership that results in some joint production requires that $y > 3$.

These outcomes are consistent with common intuition. In this model, there is capital hold-up as wages within firms cannot be negotiated ex post, after capital is sunk, and, as they cannot be replaced, the workers involved in the negotiation are essential for joint production by that firm. In this situation, as Hart and Moore (1990) clearly demonstrated, ownership of the capital asset should reside with one of the essential agents rather than with an unimportant agent such as an outside owner. This is because, when choosing to invest in capital, that agent appropriates a greater share of the surplus. Nonetheless, it is not a full appropriation, and so the resulting outcome remains inefficient compared with a neoclassical situation where wages can be committed to ex-ante. Importantly, this demonstrates that firm ownership matters as this results in potentially different efficiency properties of the resulting

[18]One way this might arise is if there is a separate capitalist class. However, this is not necessary. Workers can own firms, but not the firms they are employed by.

equilibrium. As will be demonstrated in what follows, however, this specific welfare ranking is not robust to ownership becoming endogenous.

3 Equilibrium with Endogenous Ownership

We now turn to consider the equilibrium outcome when firm ownership is endogenous. Endogeneity means that firms can be formed and also eventually owned by either managers or other outside agents (both those in self-production or employed at other firms).[19] As will be demonstrated, the distinction between firm formation and eventual ownership is important and determines the nature of equilibrium outcomes that emerge.

In what follows, we work backwards. First, the outcomes from ex post asset trading are examined, holding firm formation and skill acquisition as fixed. Second, initial firm formation is examined in anticipation of the outcomes from ex post asset trading.

3.1 Ex Post Asset Trading

Suppose that N firms have formed with $L = 2N$ workers having firm-specific skills. Then self-production wages, $w(N) = (2N)^{1/\eta}$. To explore ex-post trading, we consider firms that are initially O-owned and those that are initially M-owned:

- Suppose that a firm is initially O-owned. If no asset trade occurs, the outside owner expects to earn $\frac{1}{3}(y - 2w)$. If an asset were traded to a manager, then the manager would earn $\frac{1}{2}y$ instead of $\frac{1}{3}(y + w)$ they would earn under O-ownership. It is easy to see that, so long as $y \geq 2w$, the outside owner's willingness to sell, $\frac{1}{3}(y-2w)$, is greater than the willingness to pay of the manager, $\frac{1}{2}y - \frac{1}{3}(y + w) = \frac{1}{6}(y - 2w)$. Thus, the asset would remain O-owned. If $y < 2w$, the willingness to sell of the outside owner will be negative but less than the (negative) willingness to pay of the manager, and so the asset would trade to the manager.

- Suppose that a firm is initially M-owned. If no asset trade occurs, the manager expects to earn $\frac{1}{2}y$, while if the asset were traded to an outside owner, the manager would earn $\frac{1}{3}(y + w)$. If a trade occurs, the outside owner expects to earn $\frac{1}{3}(y - 2w)$. Again, it is easy to see that the willingness to pay of the outside owner, $\frac{1}{3}(y - 2w)$, is more than the willingness to sell of the manager, $\frac{1}{2}y - \frac{1}{3}(y + w) = \frac{1}{6}(y - 2w)$. Thus, so long as

[19] The skilled worker who has skills specific to the capital of a particular firm is excluded here from ownership. This is done to simplify the analysis. It would be possible to allow such workers to also own firms, with all of the conclusions derived below still holding, so long as it was assumed that the two skilled agents could not collude or cooperate over ownership of their specific firm. See Gans (2005).

$y \geq 2w$, the manager will sell the asset to an outsider. Otherwise, the asset will remain M-owned.

This demonstrates that so long as $y \geq 2w$, following the asset trading period, the asset will be owned by an outsider, while if $y < 2w$, the asset will eventually be owned by the manager. This, of course, raises the question of whether it is possible that $y < 2w$. If this arose, then the manager would be better off shutting the firm down. As will be demonstrated below, this implies that we would not expect the firm to form if y is expected to be lower than $2w$.

This may appear to be a surprising result, given that the outside owner does not actually add anything productive to the joint-production sector. However, as Gans (2005) showed, it is precisely because outsiders do not play a productive role that they are motivated to bid for ownership as a means of gaining any ex post rents. By contrast, a manager who plays a productive role receives benefits even when they are an employee and not an owner, which mutes their willingness to pay. Notice also that this same outcome would arise ex post after the asset has been created at a cost of 1. A manager would find it worthwhile to sell ownership to an outsider, while an outsider would be unable to convince a manager to purchase ownership for more than the outsider's expected ex-post profits. As will be seen in what follows, what is new here is that this prediction is robust and has implications for firm formation when labour market outcomes are endogenous rather than given as is typically assumed in the property rights theory of the firm.[20]

3.2 Firm Formation

Any agent, whether they intend to work in joint production or not, can form a firm by investing in one unit of the consumption good. We will consider the formation choices of outside owners and managers, respectively:

- An outside owner who forms a firm expects to earn $\frac{1}{3}(y - 2w) - 1$.
- A manager who forms a firm expects that, so long as $y \geq 2w$, the firm's assets will be sold to an outside owner prior to production taking place. As asset markets are competitive ex post, the manager will expect to earn $\frac{1}{3}(y+w)+\frac{1}{3}(y-2w)-1 = \frac{1}{3}(2y-$

[20] It is instructive to note why this outcome would not change if the other skilled worker could bid for ownership. If the manager sells to an outsider, the manager receives $\frac{1}{3}(y - 2w) + \frac{1}{3}(y + w) = \frac{2}{3}y - \frac{1}{3}w$. The skilled worker is willing to bid up to $\frac{1}{2}y - \frac{1}{3}(y + w)$ to block this outcome. If it did bid this much, the manager would receive $\frac{1}{2}y + \frac{1}{2}y - \frac{1}{3}(y + w) = \frac{2}{3}y - \frac{1}{3}w$; the same amount as they would receive from an outsider. However, as Gans (2006) shows, this leaves the manager vulnerable to expropriation by the skilled worker who can threaten to sell to outsiders. Thus, in a full game, the manager prefers to sell to outsiders to avoid this possibility.

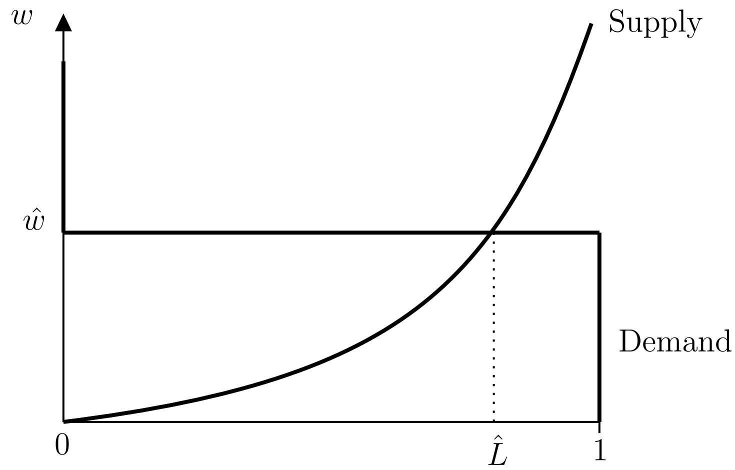

Figure 1: General Equilibrium Outcome

$w) - 1$. If the manager does not form the firm, they expect to earn w in self-production. Thus, the net return to a manager forming a firm is $\frac{1}{3}(2y - w) - 1 - w = \frac{2}{3}(y - 2w) - 1$.

In each case, the return to forming a firm will only be positive if $y \geq 2w$. Therefore, we now consider whether this will be the case in equilibrium.

Note, first, there is a higher return to a manager forming a firm than an outsider. Thus, suppose that the marginal firm is formed by a manager. In this case, the firm will form so long as the return is non-negative. That is:

$$\tfrac{2}{3}(y - 2w) \geq 1 \implies y \geq \tfrac{3}{2} + 2w$$

If this inequality holds with equality (i.e., the firm formation constraint binds), then, in equilibrium:

$$\hat{w} = \tfrac{1}{2}(y - \tfrac{3}{2})$$

which implies that if wages are to be positive, $y > \frac{3}{2}$. Regardless:

$$y \geq 2\hat{w} \implies y \geq y - \tfrac{3}{2}$$

which always holds. This is an interior equilibrium – with labour allocated to both joint and self-production – if $\hat{w} < 1$ or $y < 3$ (as already assumed). This outcome is presented in Figure 1. Note that, at this wage, the returns to an outside owner forming a firm are negative; that is, $\frac{1}{3}(y - 2w) = \frac{1}{2} < 1$.

3.3 General Equilibrium Outcome

Given this, we have demonstrated the following proposition:

Proposition 1 *(i) If $y > \frac{3}{2}$, the unique equilibrium outcome involves managers forming firms and then selling to outsiders. Self-production wages and manager total income (wage + entrepreneurial profit) are $\frac{2y-3}{4}$, skilled worker wages are $\frac{2y-1}{4}$, outsider returns are 0 and $C = \frac{1}{2}(y-1)\left(\frac{2y-3}{4}\right)^{\eta} + \frac{\eta}{1+\eta}\left(1 - \left(\frac{2y-3}{4}\right)^{1+\eta}\right)$. (ii) If $y < \frac{3}{2}$, the unique equilibrium involves no joint production and all output is from self-production with zero wages and $C = \frac{\eta}{1+\eta}$.*

Appendix B contains a proof of this proposition for a general environment with multiple production sectors and commodities. Proposition 1 demonstrates that under endogenous ownership, firms are formed by managers while they are eventually owned by outsiders employing the founding manager as a manager-employee.[21] Therefore, from the perspective of whether firms in general equilibrium ought to be modelled as owned by a factor of production with income part of the earnings of that factor or as being owned by households (i.e., outside parties), this model demonstrates that the latter, with profits counted as income accruing to households, will be a reasonable approach for modelling economies once firms have already formed. By contrast, when considering firm formation itself as well as the distribution of wealth arising from ownership, that wealth is accrued by individual factors of production (in this case, labour endowed with managerial skills). Thus, the distinction between the Arrow-Debreu and McKenzie approaches to ownership of profits is more subtle when ownership of assets is endogenous.

With respect to welfare, the equilibrium that arises under endogenous firm ownership leads to a more joint production than in either case where firm ownership is endogenous. Specifically, firms will form even where $y < 2$, although some firms that would be efficient in equilibrium are not formed. The reason for the improvement in efficiency comes from the ability to asset ownership to be determined ex post. This means that a manager can form a firm and, in expectation, earn not only the returns from their eventual employment by that firm but also the rents associated with pure ownership that are eventually transferred from acquiring outside owners. This raises the returns to firm formation above what a manager who could not engage in ex post restructuring of ownership could earn.

Finally, it is useful to note the distribution of wealth and income in equilibrium. Skilled workers earn the highest income, while managers and self-production workers earn equal amounts. Returns on asset ownership are zero. Thus, there is no issue of how to distribute

[21] When $y = \frac{3}{2}$, initial firm ownership is indeterminant although firms are eventually owned by outsiders in equilibrium.

such returns to households, while whatever returns there are to firm formation are competed away by the formation of such firms.

In terms of the ex post distribution of income and consumption (after asset creation and acquisition costs), all skilled workers earn the same income (both managerial and other), and, as they are scarce ex post, this income exceeds their self-production wage. By contrast, self-production workers earn their marginal productivity, which may exceed the wage for all but the marginal self-production worker, in equilibrium. Finally, outside owners earn income at a rate that is less than that of skilled workers.

3.4 Discussion of the Model

The implication of the result here is that firm formation by what we could call 'entrepreneurs' is the natural prediction in a general equilibrium environment. This arises in an environment where it is possible for a consortium of outside investors to be responsible for firm formation. Moreover, this result is accompanied by another strong prediction that the ultimate ownership of firms will reside with those outsiders, even though they are not directly involved in productive activities in the economy and are pure capital owners. In other words, the central stylised fact of entrepreneurship, that entrepreneurs found firms but exit to ownership structures that leave them without control, arises as an implication of general equilibrium theory with endogenous ownership.

In that regard, the model here provides a new prediction as to who becomes an entrepreneur. In this model, entrepreneurs are agents who undertake initial investments in firm formation (here modeled as capital investment but could also be easily conceived of as time or risk bearing) who (a) can become sellers in ex post asset markets and (b) are expected to return some value creating role in the firm even after they have ceded ownership and control. To see this, note that the expected return to an agent who decides to form a firm is:

$$\text{Expected Exit Value} + \text{Post-Exit Earnings at the Firm} - \text{Investment Cost}$$

as compared to outside investors who would receive only:

$$\text{Expected Exit Value} - \text{Investment Cost}$$

if they formed a firm. Importantly, it is the expectation of *some* post-exit earnings that creates the superior incentive for an entrepreneur to found a firm. Thus, the prediction of the model characterises an entrepreneur as an agent who is 'important' to firm value regardless of whether they own the firm or not.

It is here that the model differs from the property rights approach of Hart and Moore (1990). In that model, an owner is an agent who needs the superior bargaining position that comes from ownership to motivate them to engage in non-contractible productive activities. If this were an entrepreneur, they would act to increase firm value in the form of ongoing earnings in the Hart-Moore world. Here, however, as asset markets are open and clear ex post, the entrepreneur considers value upon exit. In other words, to the extent that the entrepreneur was expected to engage in non-contractible investment or effort, their choices are based on returns *after* ownership has been ceded to outsiders. When an entrepreneur founds a firm with the expectation of selling it, they do not consider simply the impact on value they capture ex post (their Post-Exit Earnings), but also on the value from the asset sale. Thus, while, for example, the entrepreneur of an M-owned firm will consider the impact on one-half of value created in choosing those non-contractible actions, and an agent who is employed by an outside owner, one-third of value created, here, the entrepreneur founder considers the impact on two-thirds of value created; a stronger incentive than in a model without endogenous ownership. In the model here, that non-contractible action is the choice to invest to found a firm, and so the market allocates initial ownership to the entrepreneur who appropriates the highest share of the value created by firm formation.

The general equilibrium aspect of this result comes from the impact that firm formation has on the labour market. Firm formation draws workers from self-production into joint production. This increases wages in self-production and also bargained wages in joint production, as well as impacting the return to firm formation. For outside investors, that effect is entirely negative at $-\frac{2}{3}$. For entrepreneurs, a higher prevailing wage reduces asset value but increases post-exit earnings. The net effect of this is negative at $-\frac{1}{3}$. Thus, the relative (gross) returns to entrepreneurial firm formation (before subtracting the entrepreneur's own wage opportunity cost) are increased. At the point where these equal self-production wages, the returns to firm formation by outsiders are necessarily negative. This creates the sharp result in Proposition 1.

What constrains firm formation, therefore, is the cost of inducing labour into joint production. This is why the rents from firm formation end up accruing to labour. Of course, it is not lost on us that this stands in contrast to a narrative that capitalist firm formation is often associated in informal discussions with rents accruing to capital rather than labour. While one suspects that financial constraints and opportunities may account for the differing implications, this paper does not attempt to resolve this tension and, instead, focus on what a general equilibrium approach reveals.

Resources other than labour could conceivably impact firm formation. For instance, opportunities for new form formation could come from the emergence of new ideas. Romer (1990) famously modelled these as arising out of ideas for new products, the investment costs for which involved the licensing of patent rights. Given that the flow of such ideas might be constrained by factors other than labour, this could also drive the scarcity of firm formation. This suggests that, like traditional general equilibrium theory, there is scope for embedding endogenous ownership in other environments studying broader economic issues.

4 Incomplete Contracts

In the baseline model, any efficiency that arises is because when firms are formed, the capital invested is nonfungible, leading to a hold-up problem, as skilled labour that brings joint production value to that capital is irreplaceable. Below, we will explore the outcomes that arise when these assumptions are relaxed. However, it is instructive to first consider what happens when ownership structure can impact the productivity of joint production itself. Here, we will explore contractual incompleteness that can generate such outcomes.

The decision to invest and form a firm is non-contractual in the baseline model, and Proposition 1 shows that a manager (aka entrepreneur) is both predicted and the (constrained) efficient agent to undertake that action. As there is often discussion regarding the social importance of providing incentives for entrepreneurs to engage in such investments and firm-building activities, the results thus far suggest that market forces will support and provide such incentives. This would, of course, include any non-contractible actions taken by managers that will boost y in the long term. As is well-known, for such long-term actions, it is the eventual ownership structure that drives incentives rather than the initial ownership structure per se. The same is true in the baseline model, with the caveat that the eventual ownership structure drives both the ongoing wage earnings of the manager and the sale price of assets. It is for this reason that a manager's incentives to invest are stronger than other agents.

Here, we explore the role of incentives to undertake non-contractible but productive activities that impact ongoing firm performance. Such activities can be undertaken by any skilled worker, manager or otherwise. The difference is that ownership structure can impact incentives to undertake such activities and, in the process, impact ex post asset trading that would alter ownership structure. In this section, these issues are explored by focusing on non-contractible actions undertaken by other skilled workers. However, it is noted that these would equally apply to the manager as well with regard to actions that impact ongoing firm performance.

To this end, suppose that the skilled worker can engage in an activity, incurring a personal cost of c, and increase firm output by $\Delta > 0$ to $y + \Delta$. It is assumed that such activity is efficient with $c \leq \Delta$. Suppose that activity is not contractible and, thus, cannot be directly determined via wage negotiations within a firm. In this case, a skilled worker will choose to engage in the productivity-improving activity if:

1. Under M-ownership, $\frac{1}{2}(y + \Delta) - c \geq \frac{1}{2}y$ or $\frac{1}{2}\Delta \geq c$.

2. Under O-ownership, $\frac{1}{3}(y + \Delta + w) - c \geq \frac{1}{3}(y + w)$ or $\frac{1}{3}\Delta \geq c$.

As is well known in the property rights literature (Hart and Moore, 1990), the worker has greater incentives to engage in productive activity if the firm is owned by another essential agent (in this case, the manager) rather than an outside owner who plays no productive role.

To focus on the interesting case where ownership matters, it is assumed that:

$$3 > \frac{\Delta}{c} \geq 2$$

In this case, if the firm is eventually under M-ownership, its output will be $y + \Delta$; otherwise, under O-ownership, it is simply y. This will impact the outcomes that arise from asset trading.

When ownership matters for efficiency, this will impact ex post asset trading by altering a manager's willingness to sell and an outsider's willingness to pay for the asset. Thus, O-ownership will arise if:

$$\underbrace{\tfrac{1}{2}(y + \Delta) - \tfrac{1}{3}(y + w)}_{M \text{ willingness to sell}} < \underbrace{\tfrac{1}{3}(y - 2w)}_{O \text{ willingness to pay}} \implies \Delta < \tfrac{1}{3}(y - 2w)$$

Thus, for Δ high enough, the equilibrium outcome will be M rather than O-ownership. Intuitively, there is more surplus available when the skilled worker has an incentive to engage in the productive activity.

While this result – that trading of ownership can result in an inefficient allocation of assets under contractual incompleteness – has been explored in the literature (Gans, 2005), the general equilibrium context adds an important caveat to the analysis. Under general equilibrium, whether it M-ownership is an equilibrium depends on another factor: the skilled worker's *participation constraint*. Under M-ownership, a worker has three choices: (i) engage in effort resulting in an expected payoff of $\frac{1}{2}(y + \Delta) - c$; (ii) refrain from effort for $\frac{1}{2}y$ and (iii) return to the self-production sector for w. The worker will choose (i) over (ii) given our assumption that $\frac{\Delta}{c} \geq 2$. However, for (i) to be preferred to (iii) requires $\frac{1}{2}(y + \Delta) - c \geq w$. However, w depends on total firm formation and joint production employment under the condition that worker effort is expended. Thus, if, consistent with a M-ownership equilibrium, $w_M = \frac{1}{2}(y + \Delta - 2)$, for the worker participation constraint to hold requires $\frac{1}{2}(y + \Delta) - c \geq w$ or $c \leq 1$. This is because wages in self-production are driven by joint-production productivity less a capital cost share, but can be obtained without incurring c.[22]

This means that the approach to determining the equilibrium just discussed will not be appropriate if $c > 1$. In this case, the worker participation constraint will bind, not the firm formation condition. Given this, the following proposition characterises the equilibrium outcomes in the model with incomplete contracts and endogenous ownership.

Proposition 2 *Suppose that $\frac{\Delta}{c} \in [2, 3)$. If $c \leq 1$, the equilibrium outcomes are as follows:*

1. *(M-ownership, Firm Constrained) If $y + \Delta \geq 2$, $\Delta \geq \frac{1}{2}$ and $c \leq 1$, there exists an equilibrium with M-ownership ex post, with self-production wages and manager income (net of capital cost) of $\frac{1}{2}(y + \Delta - 2)$ and skilled worker payoff of $\frac{1}{2}(y + \Delta) - c$.*

2. *(M-ownership, Worker Constrained) If $y + \Delta \geq 2c$ and $c \geq 1$, there exists an equilibrium with M-ownership ex post, with self-production wages and skilled worker payoff of $\frac{1}{2}(y + \Delta) - c$ and manager income of $\frac{1}{2}(y + \Delta) - 1$.*

3. *(O-ownership, Low Productivity) If $y \geq \frac{3}{2}$ and $\Delta \leq \frac{1}{2}$, there exists an equilibrium with O-ownership ex post with the same payoff outcomes as Proposition 1.*

The proposition demonstrates that there are two types of equilibrium within the assumed zone of interest where ownership matters (i.e., $\Delta/c \in [2, 3]$). The first is the M-ownership outcome, where the firm formation constraint binds, which is an equilibrium if Δ is sufficiently high and c is less than firm formation capital costs. The second is an M-ownership outcome where the skilled worker participation constraint binds. This is an equilibrium if c is greater than the firm formation capital costs. In this equilibrium, it is manager income that exceeds self-production wages, while skilled worker payoffs are the same in and out of joint production. If Δ is low ($< 2c$), there exists a further equilibrium involving O-ownership with low productivity as the worker employed by the firm does not engage in productivity-increasing effort.

Figure 2 shows the equilibrium outcomes in (c, Δ) space. Note that if $\Delta < 2c$, then no worker engages in the productive activity and the unique equilibrium is O-ownership (with low productivity) as in Proposition 1. On the other hand, if $\Delta > 3c$, then workers engage in the productive activity even under O-ownership. In this case, the nuances regarding the

[22] Note that this particular issue would also arise if ownership were exogenous, but there were incomplete contracts.

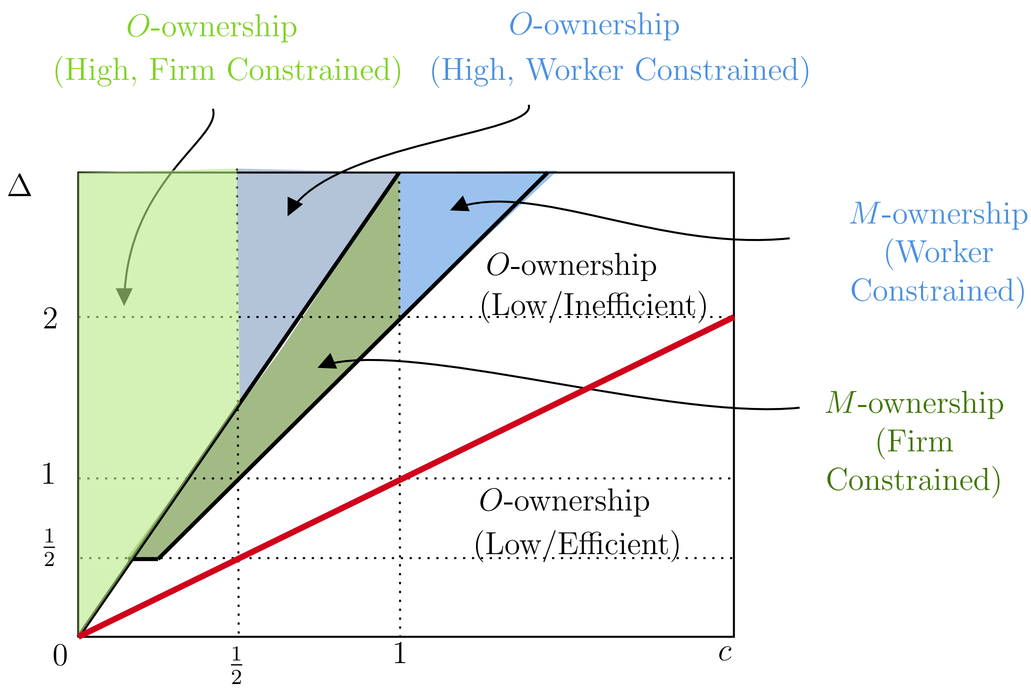

Figure 2: Equilibrium Outcomes with Incomplete Contracts

skilled worker participation constraint will come into play. If $\hat{w}_O = \frac{1}{2}(y + \Delta - \frac{3}{2})$, the worker participation constraint requires that $\frac{1}{3}(y + \Delta + \hat{w}_O) - c \geq \hat{w}_O$ or $c \leq \frac{1}{2}$. Thus, if $c > \frac{1}{2}$, the worker participation constraint will bind, resulting in $\hat{w}_O = \frac{1}{2}(y + \Delta - 3c)$ while the returns to the manager from firm formation will be strictly positive.

Finally, Figure 2 shows that regardless, endogenous ownership implies that equilibrium outcomes will be inefficient beyond the capital hold-up modelled earlier. Above the red line, it is efficient to engage in effort to boost productivity. When there are incomplete contracts impacting on worker effort, this can allow M-ownership to emerge but only if Δ is sufficiently higher ($\geq \frac{1}{2}$). Otherwise, O-ownership prevails.

It is useful to observe that while O-ownership can arise when it is efficient to undertake the productive activity, this does not necessarily imply that M-ownership would be welfare-enhancing in the sense of creating higher aggregate consumption in equilibrium. This is because O-ownership arises precisely because the returns to investment anticipating O-ownership are higher than the returns to investment if M-ownership were imposed. Thus, for Δ such that:

$$\tfrac{2}{3}(y - 2w) + w = 1 + \tfrac{1}{2}(y - \tfrac{3}{2}) \geq \tfrac{1}{2}(y + \Delta) \implies \tfrac{1}{2} \geq \Delta$$

imposing M-ownership would reduce total firm formation and mitigate the productivity benefits that it brings. This is because the ownership structure balances the incentives of managers for long-term non-contractible actions against the incentives of skilled workers for ongoing non-contractible actions. The nuance added by the analysis here is that, in contrast to Hart and Moore (1990), those long-term incentives are best promoted by outside as opposed to manager ownership.

5 Robustness

The previous section has a strong prediction that when ownership is endogenous, firms are formed by managers who then trade firm assets to outsiders. Thus, the resulting equilibrium is outside-ownership. In this section, the various assumptions in the baseline model are tested to see how robust this prediction is. It will be demonstrated that while altering those assumptions can change the efficiency outcomes from the resulting equilibrium, the main prediction is robust to such changes.

5.1 Fungible Capital

A key assumption in the baseline model is that capital, once deployed, cannot be reutilised for consumption; that is, it is non-fungible. This allows for capital hold-up by agents (both skilled workers and managers) whose skills are specialised to the firm's capital asset and who are scarce ex post. Here, the assumption that capital is non-fungible is relaxed, and it is demonstrated that this does not change the O-ownership equilibrium outcome but, in the limit, does restore efficiency.

Suppose that capital is fungible and can be converted into $\alpha(< 1)$ of the consumption good at no cost. This fraction becomes part of the bargaining surplus between the firm owners and workers, i.e., $s = y - \alpha - 2w$. Under O-ownership, this surplus is split three ways, giving $\frac{1}{3}s + w$ to the manager and skilled worker and $\frac{1}{3}s + \alpha$ to the owner. By contrast, under M-ownership, the worker receives $\frac{1}{2}s + w$ and the manager receives $\frac{1}{2}s + \alpha + w$. Note that this implies that in ex post trading, the willingness to pay of outsiders always exceeds the willingness to sell of the manager:

$$\underbrace{\tfrac{1}{3}(y + 2\alpha - 2w)}_{O \text{ Willingness to Pay}} > \underbrace{\tfrac{1}{2}(y + \alpha) - \tfrac{1}{3}(y - \alpha + w)}_{M \text{ Willingness to Sell}} = \tfrac{1}{6}(y + 5\alpha - 2w) \implies y - 2w \geq \alpha$$

which holds so long as there is a positive surplus from joint production at the equilibrium wage.

Given this, the firm formation condition is now:[23]

$$\tfrac{1}{3}(y+2\alpha-2w)+\tfrac{1}{3}(y-\alpha+w)-1\geq w \implies \tfrac{2}{3}(y-2w)\geq 1-\tfrac{1}{3}\alpha$$

If the manager firm formation condition holds with equality, we can derive the equilibrium wage as:

$$\hat{w}_O=\tfrac{1}{4}(2y+\alpha-3)$$

Thus, firms will be formed so long as $y\geq\frac{3-\alpha}{2}$, and the equilibrium outcome will involve managers forming firms and, ultimately, O-ownership. Importantly, as $\alpha\to 1$, the condition for firm formation approaches $y\geq 1$; that is, firms form so long as joint production is efficient. This establishes that capital non-fungibility is the source of any equilibrium inefficiency.[24]

5.2 Replaceable Workers

The second assumption that potentially drives an inefficient equilibrium outcome is that workers in joint production have non-binding wage contracts that can, thus, be renegotiated by irreplaceable workers. Here, these results are re-evaluated in a setting that allows skilled workers or managers to be replaced by workers from the self-production sector.

To examine this, we consider an alternative wage bargaining model based on that of Stole and Zwiebel (1996a) but where workers can be replaced from the pool of labour in self-production, thereby generating an outcome different from the Shapley value. We utilise the model of de Fontenay and Gans (2003) that determines negotiated wage outcomes when there are replacement workers and employment contracts are non-binding. Specifically, their model demonstrates that the joint-production employment wage when there are l agents in self-production is:

$$e^{-l}\tfrac{1}{3}(y+w)+(1-e^{-l})w$$

for O-ownership and

$$e^{-l}\tfrac{1}{2}y+(1-e^{-l})w$$

for M-ownership where, in each case, the fact that workers are drawn from a continuum is taken into account. Note that replacement workers come from self-production and are assumed not to be drawn from joint production.

How does this change ex post asset trading? Outside owners will end up with the asset

[23] Note that the net return to outside owners forming firms is $\frac{1}{3}(y+2\alpha-2w)-1$, which is lower than the net return to managers forming firms.

[24] If $\alpha=1$, then firm formation is efficient and a founding manager's net return exceeds that of a founding outsider.

if and only if:

$$\underbrace{y - 2(e^{-l}\tfrac{1}{3}(y+w) + (1-e^{-l})w)}_{O \text{ Willingness to Pay}} > \underbrace{y - (e^{-l}\tfrac{1}{2}y + (1-e^{-l})w) - (e^{-l}\tfrac{1}{3}(y+w) + (1-e^{-l})w)}_{M \text{ Willingness to Sell}}$$

$$\implies e^{-l}\tfrac{1}{3}(y+w) < e^{-l}\tfrac{1}{2}y \implies y > 2w$$

Given this, the following result can be proven:

Proposition 3 *Suppose that joint production firms can negotiate and replace workers from the self-production sector. Then, if* $y \geq \frac{3e}{3e-1} \approx 1.14$*, the unique equilibrium outcome involves managers forming firms and then selling them to outsiders.*

The proof of the proposition is in the appendix. The challenge in the proof arises because the condition for equilibrium wages must take into account the impact of the wage on the size of the self-production labour pool. That pool is limited and becomes more so, the more joint production firms are formed. This creates an additional effect that increases negotiated wages. Nonetheless, the proposition demonstrates that the conditions under which joint production takes place in equilibrium is expanded and, thus, worker replaceability serves to increase efficiency.

Thus, so long as it is feasible, O-ownership remains the equilibrium outcome. The ability to replace workers means that the range of parameters for which O and M-ownership are feasible is greater than the no-replacement case. However, it is only when the measure of the set of agents approaches infinity (a highly unrealistic case) that an efficient outcome arises.

5.3 Non-Specific Skills

Skilled workers have skills specific to the firm they join, whether those skills are managerial or not. This means that in wage negotiations, their outside option is to engage in self-production. For the capital owner, this implies that in the absence of an agreement, the firm cannot operate, and the capital asset has no value. Suppose, instead, that skills are transferable between firms, although the type of skills remains distinct. That may alter the outside options of both the skilled workers and the firm. As will be shown in this section, this change adds considerable complexity to the analysis. However, the results of Proposition 1 continue to hold.

The baseline model allowed the use of the Shapley value between two or three agents, as the case may be, because those were the only agents who could generate joint production output in a coalition. When skills are non-specific, if there are $[0, 2n]$ skilled workers ($[0, n]$ of each type), $[0, n]$ firms can form, but the workers can have a positive marginal contribution to any of those firms. If we suppose, as would be consistent with general equilibrium models, that agents of the same type cannot cooperate (or collude), then the cooperative bargaining output is graph-constrained. Nonetheless, all agents are connected in the resulting graph and, thus, as demonstrated by Myerson (1977), the resulting allocation of value is the same as the Shapley value across all skilled workers and capital asset owners.[25] The complication for the model here is that the agents concerned come from a continuum. For this reason, the appendix A.3 shows that when the set of agents is a continuum, the Shapley value allocations described below arise.

The straightforward way to see this is to note that because of the symmetry condition of the Shapley value, the payoffs to agents of a given type: skilled workers, managers, outside capital owners and manager-owners will all be identical. Thus, if a measure N of firms form, then aggregate joint production surplus will be $n(y-2w)$. Under M-ownership, each skilled work will receive $\frac{1}{2}(y-2w)+w$ as will each manager. Under O-ownership, the surplus is split equally amongst the three agent types, with the skilled workers each receiving $\frac{1}{3}(y-2w)+w$ and outside owners as a whole receiving $n\frac{1}{3}(y-2w)$. As the number of firms is a continuum, if one pair of outside owners and managers decides to change the asset ownership of a firm, this will not change the allocation to other agents. Consequently, it will remain the case that in ex-post trading, M's willingness to sell will be less than an outsider's willingness to pay, and O-ownership will result.

One might object that this is an artifact of the assumption that agents exist in a continuum. Thus, we examine the robustness of this outcome by considering an analysis of ex post trading when agents are discrete and each skilled worker's skills are not specific to a particular firm. We will show that in this situation, if one manager and an outside owner change their asset ownership arrangements, this will impact the payoffs of all other agents.

To illustrate this, consider an environment in which only two firms have formed, and there are four skilled workers, two with each skill. Each agent receives their Shapley value in the game with 6 agents. Of the two firms exist under O-ownership, each worker receives $\frac{1}{3}(y+w)$ and each outside owner receives $\frac{1}{3}(y-2w)$. Under M-ownership, the manager and worker each receive $\frac{1}{2}y$ ex post. To calculate the gains from trade from ex post asset trading, we need to calculate the Shapley values if just one firm is M-owned while the other is O-owned. In the resulting 5-agent game, the Shapley values have the manager of the manager-owned firm earning $\frac{17}{30}(y-2w)+w$, the outside owner of the outsider-owned firm earning $\frac{19}{60}(y-2w)$, the manager employed by that firm earning $\frac{19}{60}(y-2w)+w$ and the two other skilled workers earning $\frac{2}{5}(y-2w)+w$. Intuitively, the outside owner and the employed

[25] de Fontenay and Gans (2014) provides a non-cooperative game based on bilateral contracts between the capital asset holder and any worker that generates the Shapley value allocation.

manager have the same contribution to net surplus and, by symmetry, will receive the same share of net surplus $(y-2w)$. The same logic holds for the other skilled workers.

Intuitively, starting from a situation where both firms are M-owned, and each agent receives $\frac{1}{2}(y-2w)+w$ if one manager-owner sells to an outsider, that agent's payoff will fall to $\frac{19}{60}(y-2w)+w$ while the outside owner receives $\frac{19}{60}(y-2w)$, representing their willingness to pay for the asset. Comparing this to the manager's willingness to sell of $\frac{1}{2}(y-2w)+w-\frac{19}{60}(y-2w)+w=\frac{11}{60}(y-2w)$ which is less than the outsider's willingness to pay. This demonstrates that M-ownership is not an equilibrium outcome in ex post asset trading.

The surplus that enables this transaction to take place comes from the other two skilled workers whose payoffs fall to $\frac{2}{5}(y-2w)+w$. Interestingly, the payoff of the other manager-owned firm *increases* to $\frac{17}{30}(y-2w)+w$. This raises the question of whether a pure O-ownership outcome is possible. In this situation, the relevant condition for the asset to be sold to an outside owner is:

$$\underbrace{\tfrac{17}{30}(y-2w)+w-(\tfrac{1}{3}(y-2w)+w)}_{M\text{'s Willingness to Sell}} \leq \underbrace{\tfrac{1}{3}(y-2w)}_{O\text{'s Willingness to Buy}} \implies \tfrac{17}{30}(y-2w) \leq \tfrac{2}{3}(y-2w)$$

which always holds. Thus, O-ownership is the unique outcome in ex post trading even when worker skills are not firm-specific.

The following proposition proves this for the case of $[0,n]$ firms.

Proposition 4 *Suppose that there are n capital owners and n workers of each type. Then O-ownership for all n joint production firms is the unique equilibrium outcome of ex post asset trading.*

The proof (in the appendix) is quite involved but intuitively, when a manager-owner sells an asset to an outside owner, this creates a new environment with an "unbundled" manager and capital asset, making forming firms harder as other agents are "forced" to cede more value to make that happen while creating an additional outside agent dividing surplus further.[26] Both of these factors mean that the new outside owner and its manager-employee can appropriate more value than a single manager-owner could previously.

Thus, the equilibrium identified in Proposition 1 emerges as an equilibrium in a situation where worker skills are not firm-specific. The equilibrium wage outcome remains $\hat{w}_O = \frac{1}{2}(y-3)$ and, thus, in equilibrium, managers form firms that are sold to outside owners in ex post trading.

[26] An alternative proof of an O-equilibrium is provided in the appendix using a different approach based on Segal (2003).

5.4 Endogenous Firm Size

In the baseline model, joint production involves just two workers – a manager and a skilled worker – who are perfect complements for one another. A natural question to explore is what happens when there are (a) more workers who can contribute to joint production, (b) those workers are not perfect complements, and (c) the size of the firm is itself endogenous. In this subsection, we augment the baseline model to include these features and examine how this impacts ownership outcomes.

Suppose that one unit of capital and one manager allow joint production to take place according to a production function, $F(n)$, where n is the number of skilled workers employed by the firm.[27] The skills of workers are specific to the firm and cannot be used in production elsewhere. It is assumed that F is increasing and (weakly) concave in n with $F(0) = 0$. Thus, if a firm employs n workers, it generates (net) surplus of $F(n) - (n+1)w$; recalling that the manager has an outside wage option of w.

So long as $F(i) \geq (i+1)w$ for all $i \leq n$, under M-ownership, the Shapley value for the manager is:

$$\frac{1}{n+2}\sum_{i=1}^{n}(F(i) - (i+1)w)$$

This is derived by Shapley and Shubik (1967) (see also Stole and Zwiebel (1996a), who identify the condition on $F(.)$ and w which they term *feasibility*). Under O-ownership, the Shapley value for the outside owner is:

$$\frac{1}{(n+1)\,(n+2)}\sum_{i=1}^{n}\big(i+1\big)\,(F(i) - (i+1)w)$$

while the payoff for the manager in this structure is the same as the outside owner's plus w. Given this, O-ownership will be chosen over M-ownership in ex post trading if:

$$\underbrace{\tfrac{2}{(n+1)\,(n+2)}\sum_{i=1}^{n}\big(i+1\big)\,(F(i) - (i+1)w) + w}_{\text{Joint Payoff Under } O\text{-ownership}} > \underbrace{\tfrac{1}{(n+1)\,(n+2)}\sum_{i=1}^{n}\big(i+1\big)\,(F(i) - (i+1)w)}_{M \text{ Payoff under } M\text{-Ownership}}$$

Given this, we can demonstrate the following:

Proposition 5 *Let $F : \{1, 2, \ldots, n\} \to \mathbb{R}$ be any real-valued function. Suppose that, for $w > 0$,*

$$F(i) \;\geq\; (i+1)\,w \quad \textit{for all } i = 1, 2, \ldots, n.$$

[27] This specification captures the production technology envisaged by Arrow and Debreu that allows for diminishing returns to scale as well as an entrepreneurial input for each firm.

Then O-ownership is the unique equilibrium in ex post asset trading.

This demonstrates that the conclusions of the baseline model with respect to ex post asset trading carry over to the more general environment here.

Suppose that following the ex post trading stage but before production, each joint production firm chooses its 'size,' n. Stole and Zwiebel (1996a) demonstrate that in choosing n, at the optimal $\tilde{n}$:

$$F(\tilde{n}) - (\tilde{n}+1)w \doteq \frac{1}{(\tilde{n}+1)(\tilde{n}+2)} \sum_{i=1}^{\tilde{n}} \big(i+1\big)\left(F(i) - (i+1)w\right)$$

$$\implies F(\tilde{n}) - (\tilde{n}+1)w \doteq \frac{1}{(\tilde{n}+1)(\tilde{n}+2)} \sum_{i=1}^{\tilde{n}} \big(i+1\big) F(i) - \frac{2\tilde{n}+3}{6} w$$

Intuitively, the Shapley value is akin to the average product of a standard profit function and reaches its maximum where marginal profit crosses average product. When choosing their size, because skilled workers cannot be replaced ex post, a firm will choose a size to accommodate and commit to employ a larger number of those workers so as to diminish the bargaining position of any single worker. This means that the bargaining wage will be pushed to the self-production level.

Given this, recall that the condition determining firm formation is:

$$\tfrac{2}{(n+1)(n+2)} \sum_{i=1}^{n} \big(i+1\big)\left(F(i) - (i+1)w\right) + w - 1 \geq w$$

That is, a manager forms a firm (incurring the capital cost and forgoing self-production wages) in order to sell it to outside owners in ex post trading. In a rational expectations equilibrium, the manager will anticipate the firm size being $\tilde{n}$ for the anticipated w. Therefore, we can use the Stole-Zwiebel optimality result to pin down the firm formation condition as:

$$2\big(F(\tilde{n}) - (\tilde{n}+1)w\big) = 1$$

which gives:

$$\hat{w}_O = \frac{F(\tilde{n}) - \frac{1}{2}}{\tilde{n}+1}$$

This will be an interior equilibrium if $\hat{w}_O < 1$ or $F(\tilde{n}) - \frac{3}{2} < \tilde{n}$ on $F(\tilde{n}) - \frac{1}{2} < \hat{N}$ where $\hat{N}$ is the equilibrium number of firms.

In the baseline model, there is too little joint production relative to the socially optimal outcome. Here, however, this result is revised. To see this, in an efficient outcome, the size of firms would be chosen so that $\Delta F(n^*) \doteq w$ and the firm formation condition would be $F(n^*) - (n^* + 1)w = 1$ which would given a wage of $w^* = \frac{1}{n^*+1}(F(n^*) - 1)$. For the same n, this is a lower wage than $\hat{w}_O$; that is, the demand for labour in joint production is higher than the efficient labour demand. Thus, equilibrium wages will be higher than efficient wages, and the total volume of labour in equilibrium will exceed efficient levels. This is precisely the Stole-Zwiebel 'over-employment' result in this environment.

6 Conclusion

This paper has developed a theory of endogenous firm ownership in general equilibrium, demonstrating how ownership structures emerge from market forces rather than arising as artifacts of model assumptions. The analysis generates three key insights for economic theory. First, it shows that the property rights theory of the firm can be naturally embedded within general equilibrium analysis, with ownership patterns determined by the interaction of labour and capital markets. Second, it provides a novel economic rationale for entrepreneurship, identifying entrepreneurs as agents whose human capital makes them uniquely positioned to found firms even when they do not remain long-term owners. Third, it resolves the long-standing tension between Arrow-Debreu and McKenzie's approaches to firm ownership in general equilibrium theory.

The model's predictions align with several empirical regularities in firm ownership dynamics. It explains why entrepreneurs typically found firms but then sell ownership rights to outside investors while remaining as employees. This pattern emerges because entrepreneurs can capture value both through the sale price of ownership rights and through their ongoing employment relationship, while outside owners can only benefit through residual claims. The framework also provides insight into why ownership transitions tend to occur after firms are established rather than at founding.

This analysis suggests several promising directions for future research. One natural extension would be to incorporate financial market frictions and examine how they affect the timing and nature of ownership transitions. Another would be to explore how endogenous ownership interacts with innovation and growth dynamics. The model of the paper could also explore the long-standing assertion in corporate finance that the sale of firms to outside owners through IPOs requires entrepreneurs to make themselves replaceable (see Rajan (2012)), which contrasts with the findings in the present paper. Finally, the framework could be enriched to study how different legal and institutional environments affect equilibrium ownership patterns, including, importantly, the mix of capital and income taxation.

More broadly, this paper demonstrates the value of making ownership structures endogenous in economic analysis. Doing so provides new insights into firm formation, entrepreneurship, and the evolution of corporate ownership while maintaining the core structure of competitive general equilibrium theory. These insights may prove valuable not only for understanding observed ownership patterns but also for analysing how policy and institutional changes affect firm organisation and economic performance.

A Appendices

A.1 Proof of Proposition 2 (Contractual Incompleteness)

First, we examine whether an M-ownership equilibrium exists. Suppose that all firms are in M-ownership implying that $\hat{w}_M = \frac{1}{2}(y + \Delta - 2)$. The necessary conditions for this to be an equilibrium outcome are:

1. (Worker Incentive Constraint): The worker must engage in the productive activity, i.e., $\frac{1}{2}\Delta \geq c$; which holds by assumption.

2. (Worker Participation Constraint): The worker must prefer to remain with the firm than to go into self-production, i.e., $\frac{1}{2}(y + \Delta) - c \geq \hat{w}_M$ or $c \leq 1$.

3. (Asset Trading): Outsiders have a lower willingness to pay than the manager's willingness to sell, i.e., $\frac{1}{3}(y - 2\hat{w}_M) \leq \frac{1}{2}(y + \Delta) - \frac{1}{3}(y + \hat{w}_M)$ which implies that $\frac{1}{3}(2 - \Delta) \leq \frac{1}{2}(y + \Delta) - \frac{1}{3}(\frac{3}{2}y + \frac{1}{2}\Delta - 1)$; which holds for $\Delta \geq \frac{1}{2}$.

Thus, M-ownership is an equilibrium outcome so long as (i) $\frac{1}{2}\Delta \geq c$; (ii) $c \leq 1$ and (iii) $\Delta \geq \frac{1}{2}$. These three conditions can hold simultaneously so this equilibrium exists. Firms will be formed by managers and enter so long as $\frac{1}{2}(y + \Delta) - 1 \geq w$ which will hold with equality at $\hat{w}_M = \frac{1}{2}(y + \Delta - 2)$ confirming the (conjectured) equilibrium wage outcome and the first condition in the proposition.

If $c > 1$, then the participation constraint above will not hold at $\hat{w}_M = \frac{1}{2}(y + \Delta - 2)$. Therefore, rather than being set by the firm formation capital equation (or M-owner participation constraint) suppose that $\hat{w}_M$ is determined by the worker participation constraint so that $\hat{w}_M = \frac{1}{2}(y + \Delta) - c$. In that case, an M-owned firm will form if $\frac{1}{2}(y + \Delta) - 1 \geq \hat{w}_M$ or $c \geq 1$. Thus, in equilibrium, firms will form up until the point where the wage is $\hat{w}_M$ and an additional firm forming would result in a higher wage, a failed participation constraint and a negative return for firms. Thus, the worker incentive and participation constraints are satisfied. To establish an equilibrium, we need to consider whether the manager holds onto the asset ex post. The condition for this is that $\frac{1}{3}(y - 2\hat{w}_M) \leq \frac{1}{2}(y + \Delta) - \frac{1}{3}(y + \hat{w}_M)$ which is equivalent to $\Delta \geq \frac{1}{2}c$ which holds given our assumptions on $\frac{\Delta}{c}$. Thus, M-ownership is an equilibrium outcome so long as $c \geq 1$ and $y + \Delta \geq 2c$.

Second, we examine whether an O-ownership equilibrium exists. Suppose that all firms are eventually in O-ownership but are initially formed by managers implying that $\hat{w}_O = \frac{1}{2}(y - \frac{3}{2})$. The necessary conditions for this to be an equilibrium outcome are:

1. (Worker Incentive Constraint): The worker must not engage in the productive activity under O-ownership, i.e., $\frac{1}{3}\Delta < c$; which holds by assumption.

2. (Worker Participation Constraint): The worker must prefer to remain with the firm than to go into self-production, i.e., $\frac{1}{3}(y + \hat{w}_O) \geq \hat{w}_O$ which always holds.

3. (Asset Trading): Outsider willingness to pay for the asset is $\frac{1}{3}(y - 2\hat{w}_O)$ while the manager's willingness to sell depends on whether they expect their worker to expend effort or not. If they expect that effort, the manager's willingness to sell is $\frac{1}{2}(y + \Delta) - \frac{1}{3}(y + \hat{w}_O)$ which will be lower than the outsider's willingness to pay at $\hat{w}_O$ if $\Delta \leq \frac{1}{2}$. Note that, at $\hat{w}_O$, the skilled worker's participation constraint in M-ownership is $\frac{1}{2}(y + \Delta) - c \geq \hat{w}_O$ or $\Delta - 2c \geq -\frac{3}{2}$ which holds as $\Delta \geq 2c$ by assumption.

Thus, O-ownership is an equilibrium outcome so long as $\Delta \geq 2c$ which is consistent with the condition that $\Delta/c \in [2, 3)$ Firms will be formed by managers and enter so long as $\frac{1}{3}(2y - w) - 1 \geq w$ or $\frac{2}{3}(y - 2w) \geq 1$ which will hold with equality at $\hat{w}_O = \frac{1}{2}(y - \frac{3}{2})$ confirming the (conjectured) equilibrium wage outcome and the necessary condition in the proposition.

A.2 Proof of Proposition 3 (Replaceable Workers)

Recall from the text that, under ex post trading, the firm will ultimately be outsider-owned when $y > 2w$. In such a case a prospective manager decides to create an asset if their expected net return is non-negative. Working through the algebra in the text shows that the resulting wage $\hat{w}_O \in [0, 1]$ must satisfy

$$\hat{w}_O \;=\; \mathrm{RHS}(\hat{w}_O) \quad \text{with} \quad \mathrm{RHS}(w) \;=\; \frac{3\,e^{1-w^\eta}\,(y-1) - y}{2\big(3\,e^{1-w^\eta} - 1\big)},$$

see equation (9) in the paper. Define

$$f(w) \;\equiv\; w - \mathrm{RHS}(w), \quad g(w) \;\equiv\; 3\,e^{1-w^\eta}.$$

Any fixed point of the wage equation on $(0, \infty)$ is a zero of f.

Domain. The supply of labour from self–production is $L = 1 - l = w^\eta$. Since $L \leq 1$, we must have $w^\eta \leq 1$ and hence $w \in [0, 1]$. On this interval one has $w^\eta \in [0, 1]$, so $g(w) \in [3e^0, 3e^1]$, implying $g(w) - 1 > 0$ for all $w \in [0, 1]$. Consequently $\mathrm{RHS}(w)$ and thus $f(w)$ are finite and continuously differentiable on $[0, 1]$.

Monotonicity. Differentiating RHS yields

$$\frac{d}{dw}\,\mathrm{RHS}(w) = \frac{-\,\eta\, w^{\eta-1}\, g(w)}{2\,[g(w)-1]^2},$$

Because $\eta > 0$, $w^{\eta-1} \geq 0$ on $(0,1]$ and $g(w) > 1$ on $[0,1]$, the numerator in this expression is strictly negative and the denominator is strictly positive. Therefore $\mathrm{RHS}(w)$ is strictly *decreasing* on $(0,1]$. Consequently,

$$f'(w) \;=\; 1 - \frac{\mathrm{d}}{\mathrm{d}w}\,\mathrm{RHS}(w) \;=\; 1 + \frac{\eta\, w^{\eta-1}\, g(w)^2}{2\big[g(w)-1\big]^2} \;>\; 0 \quad \text{for all } w \in (0,1].$$

Thus f is strictly increasing on $[0,1]$.

Endpoint values. We now evaluate f at the endpoints of its domain. As $w \downarrow 0$ one has $w^\eta \to 0$ and $g(w) \to 3e$. A short computation gives

$$f(0) \;=\; 0 - \mathrm{RHS}(0) \;=\; -\,\frac{(3\,e-1)\,y - 3\,e}{2\,\big(3\,e-1\big)}.$$

Define $G(y) \equiv (3e-1)\,y - 3\,e$. Since $3e - 1 > 0$, the sign of $f(0)$ matches $-G(y)$. Observe that $G(y) = 0$ when $y = 3e/(3e-1)$. Hence

$$f(0) < 0 \quad\iff\quad y > \frac{3\,e}{3\,e-1}.$$

Similarly, evaluating at $w = 1$ uses $g(1) = 3$, giving

$$\mathrm{RHS}(1) \;=\; \frac{(y-1)\,3 - y}{2\,(3-1)} \;=\; \frac{2y-3}{4}, \qquad f(1) \;=\; 1 - \mathrm{RHS}(1) \;=\; \frac{7-2\,y}{4}.$$

For any $1 < y < 7/2$ one has $f(1) > 0$. (For larger y, the unique solution of $f(w) = 0$ lies at $w > 1$, which would imply $w^\eta > 1$ and a negative labour supply $L = 1 - w^\eta < 0$; such a wage is not feasible. Thus, we restrict attention to $y \in (1, 7/2)$; which is innocuous since we have already assumed that $y < 3$.)

Existence and uniqueness. Suppose first that $y > \dfrac{3\,e}{3\,e-1}$. Then $f(0) < 0$ and, as noted above, $f(1) > 0$ whenever $y < 7/2$. Because f is strictly increasing and continuous on $[0,1]$, the intermediate value theorem implies that there exists a *unique* root $\hat{w}_O \in (0,1)$ satisfying $f(\hat{w}_O) = 0$. This root is the unique positive solution of $\hat{w}_O = \mathrm{RHS}(\hat{w}_O)$ and gives the equilibrium self–production wage in the replaceable–worker case.

Conversely, if $y \leq \dfrac{3\,e}{3\,e-1}$ then $f(0) \geq 0$. Since f is increasing, it follows that $f(w) \geq 0$ for all $w \in [0,1]$. In particular, there is no strictly positive solution $w > 0$ to $\hat{w} = \mathrm{RHS}(\hat{w})$. The only solution is $\hat{w} = 0$, which corresponds to zero labour supply and no joint production. This completes the proof.

A.3 Aumann–Shapley value for a continuum of non specific skills

This subsection provides a rigorous continuum analogue of the Shapley value used in Section 5.3. When each essential input is supplied by a continuum of infinitesimal agents, the appropriate solution concept is the Aumann–Shapley value. For a nonatomic transferable-utility game with player set normalised to $[0,1]$ and worth function v, the Aumann–Shapley value assigns to an infinitesimal agent ds the average marginal contribution along the diagonal:

$$(Sv)(ds) \;=\; \int_0^1 \big[v(tI \cup ds) - v(tI)\big]\,\mathrm{d}t,$$

where I is the full player set. Under the mild regularity conditions given by Aumann and Shapley (1974) (monotonicity and absolute continuity along rays suffice here), this diagonal formula is well-defined and yields a unique value that extends Shapley's axioms to nonatomic games.

In the present environment, Skill 1, Skill 2 and Capital each have measure n of infinitesimal agents. A coalition that assembles (x_1, x_2, x_3) units of the three inputs produces net surplus $v(x) = \min\{x_1, x_2, x_3\}(y-2w)$. The function v is positively homogeneous, Lipschitz, and symmetric in its arguments, so the Aumann–Shapley value exists and is permutation invariant across inputs.

Evaluate the diagonal integral along the ray $t \mapsto (tn, tn, tn)$. At points on the diagonal, v has a well-defined convex set of marginal rates (the Clarke subdifferential) equal to the simplex $\mathrm{co}\{e_1, e_2, e_3\}$ scaled by $(y - 2w)$. Symmetry and anonymity imply that any measurable selection used in the Aumann–Shapley integral must assign the same component to each input, hence $\frac{1}{3}$ for Skill 1, Skill 2 and Capital at almost every $t \in [0,1]$. Integrating over t yields a value of $\frac{1}{3}(y - 2w)$ per unit of measure for each input class. Because each input class has measure n, the total payoff to each class is $\frac{n}{3}(y - 2w)$ and the grand surplus $n(y - 2w)$ is split equally.

An equivalent derivation is obtained by discretising each input into M equal blocks, computing the Shapley value in the finite $3M$-player game with characteristic function $v_M(S) = (y - 2w)\min\{X_1(S), X_2(S), X_3(S)\}$, and letting $M \to \infty$. By symmetry and the convergence of discrete Shapley values to the Aumann–Shapley value (Aumann and Shapley, 1974, chapters II–IV), the discrete payoffs per unit of measure converge to $\frac{1}{3}(y - 2w)$ for each input.

Under symmetric bottleneck technology with a continuum of non specific skills, the continuum Myerson–Shapley (Aumann–Shapley) value divides the net surplus equally, assigning $\frac{1}{3}(y-2w)$ per unit of measure to Skill 1, Skill 2 and Capital.

A.4 Proof of Proposition 4 (Non-Specific Skills)

This proposition examines the Shapley allocations in a cooperative game with four types of agents — manager–owners (MO), managers (M), skilled workers (S) and outside capital owners (O) — and shows that ex post trading leads uniquely to outside ownership. We consider an economy with n potential firms (each requiring one unit of managerial skill, one unit of labour and one unit of capital) and focus on two scenarios. In the first, one firm is manager–owned and the remaining $n-1$ firms are separately owned; in the second, one firm is outsider–owned and the remaining $n-1$ are manager–owned. In both cases, the grand coalition produces $n(y-2w)$ units of net surplus once outside wages w have been paid.

(a) Existence: outsider ownership. Let v^m denote the cooperative game in which there are m manager–owned firms, $(n-m)$ pure managers, $(n-m)$ outside owners and n workers. The value $v^m(C)$ of a coalition C is the maximum number of complete triplets (managerial skill, labour, and capital) that C can assemble, multiplied by $(y-2w)$. Thus $v^m(C) = (y-2w)\min\{\#\text{managers}, \#\text{skilled}, \#\text{capital}\}$, where the manager–owners contribute to both the manager and capital counts.

We first show that when $m=1$, the unique Shapley–value allocation produces a weak ordering $\phi_O+\phi_M \geq \phi_{MO}$. The Shapley value of a player is the expected marginal contribution of that player when agents enter in a uniformly random order. In this assignment–type game, each player's marginal contribution is either zero or one: a new manager (respectively worker, owner) forms an additional triplet exactly when the coalition accumulated so far has strictly fewer managers (respectively workers, owners) than the other inputs. A manager–owner combines both inputs but can increase the triplet count only by one at a time.

Symmetry implies that all pure managers receive the same share and all pure owners the same share. Consider a random ordering of the $3n-1$ agents. A manager–owner is pivotal if and only if, just before that agent arrives, the coalition has produced t units and both manager and capital counts are exactly t while the number of workers is at least t. By contrast, a pure owner is pivotal whenever the number of capital owners lags behind managers and workers; with a manager–owner and $(n-1)$ other owners, pure owners pivot more frequently. Similarly, a pure manager pivots whenever managers are the limiting input. Counting such pivot events shows that the combined pivot probability for an outsider–owner and a manager strictly exceeds the pivot probability of the manager–owner. Formally, let $P_{MO}(t)$ be the probability that a manager–owner is pivotal when t units have been produced. Analogously let $P_M(t)$ and $P_O(t)$ be the pivot probabilities for a pure manager and a pure owner. One can check that $P_M(t) + P_O(t) > P_{MO}(t)$ for each $t < n$, because splitting an MO agent into separate manager and owner allows the two new agents to resolve both shortfalls, whereas the bundled agent can resolve only one. Summation over t therefore yields $\phi_M + \phi_O > \phi_{MO}$. Hence, an outsider values the asset more than a manager–owner. By the same argument, all manager–owners prefer to sell their assets to outsiders, and in the post-entry equilibrium, the only trades that survive are those in which outsiders own the firms. That is, $m = 0$ is an equilibrium.

(b) Non–existence of pure manager ownership. Next, we show that when $m = n$ (all firms are manager–owned), the manager–owners strictly prefer to sell to outsiders. In this case, there are no pure capital owners; the manager–owners must supply both manager skill and capital to complete each triplet. For coalitions just short of forming a firm, the pivot probability of a manager–owner is lower than that of an outsider were one available, because a would-be owner would reduce the probability that capital is the limiting input while increasing the pivot probability of the remaining managers. A direct combinatorial argument therefore shows that a manager–owner's Shapley value is lower than the outsider–owner's Shapley value in the same game with one fewer manager–owner. As a result, each manager–owner would sell to an outsider at the trading stage, contradicting any pure M-ownership outcome. We conclude that $m = n$ cannot be sustained as an ex-post equilibrium.

(c) Uniqueness of outsider ownership. It remains to rule out any intermediate configuration $1 \leq m < n$. We prove that for all m in this range, a manager–owner has a lower Shapley payoff than the sum of a pure manager's and a pure owner's Shapley payoffs in the game with $m - 1$ manager–owners. In other words,

$$\phi_{MO}(m) < \phi_M(m-1) + \phi_O(m-1).$$

The argument constructs an injective mapping from the marginal contributions of a particular manager–owner in the m–game to the marginal contributions of a corresponding manager and owner in the $(m-1)$–game. Label the manager–owner under consideration by MO^* and remove it from v^m. In the $(m-1)$–game, introduce two new agents, M^* and O^*, representing the separated manager and owner, and retain all other agents. For any coalition $T \subseteq N_m \setminus \{MO^*\}$, define a coalition T' in the $(m-1)$–game by replacing MO^* by M^* and

O^* and adding one extra outside owner if necessary to keep the capital count consistent. Because M^* and O^* can each alleviate a shortage in manager skill or capital; their combined marginal contribution in v^{m-1} to T' is at least as large as the marginal contribution of MO^* to T in v^m. In fact, it is strictly larger whenever T has a shortfall in both manager skill and capital, since MO^* can only fix one deficit, whereas $\{M^*, O^*\}$ can fix both simultaneously. Summing this strict inequality over all coalitions T with the appropriate Shapley weights yields $\phi_{MO}(m) < \phi_M(m-1) + \phi_O(m-1)$. Hence, at any intermediate m, a manager–owner will accept an outsider's offer and sell their asset.

Combining parts (a)–(c) shows that the unique ex post equilibrium is pure outsider ownership ($m = 0$).

A.5 Proof of Proposition 5 (n Worker Case)

To show that outsider ownership arises when worker productivity exceeds the wage, it suffices to establish that

$$2\,\frac{1}{(n+1)(n+2)}\sum_{i=1}^{n}(i+1)\left[F(i)-(i+1)w\right] \;>\; \frac{1}{n+2}\sum_{i=1}^{n}\left[F(i)-(i+1)w\right].$$

Clearing denominators reveals that this is equivalent to

$$\sum_{i=1}^{n}\left[2(i+1)-(n+1)\right]\left[F(i)-(i+1)w\right] \;>\; 0. \tag{1}$$

Define the surplus sequence

$$G(i) \;\coloneqq\; F(i) \;-\; (i+1)w \quad \text{for } i = 1, \ldots, n,$$

and set $G(0) = 0$ for notational convenience. Because $F(i) > (i+1)w$ for all i, each $G(i)$ is strictly positive. To control the sign of (1), we impose the following economically natural monotonicity assumption on net surplus:

Monotone feasibility. For every $i = 1, \ldots, n-1$,

$$F(i+1) - F(i) \;\geq\; w.$$

Equivalently, the incremental net surplus from the $(i+1)$th worker is non-negative. Under this assumption the sequence $G(i)$ is weakly increasing, because

$$G(i+1) - G(i) = \left[F(i+1) - F(i)\right] - w \;\geq\; 0.$$

Hence $G(1) \leq G(2) \leq \cdots \leq G(n)$.

Rewrite the left-hand side of (1) in terms of $G(i)$:

$$\sum_{i=1}^{n} \big[2(i+1) - (n+1)\big]\, G(i) = \sum_{i=1}^{n} \big[2i - (n-1)\big]\, G(i).$$

It is convenient to express this as

$$\sum_{i=1}^{n} \big[2i - (n-1)\big]\, G(i) = 2\sum_{i=1}^{n} i\, G(i) \; - \; (n-1)\sum_{i=1}^{n} G(i).$$

Because $G(i)$ is non-negative, the latter sum is strictly positive if we can show that

$$\sum_{i=1}^{n} i\, G(i) \;\geq\; \frac{n+1}{2}\sum_{i=1}^{n} G(i).$$

This inequality follows immediately from Chebyshev's sum inequality: when two sequences are similarly ordered (both non-decreasing), the average of their products is at least the product of their averages. In our case, the sequence $\{i\}_{i=1}^{n}$ is increasing, and the sequence $\{G(i)\}_{i=1}^{n}$ is also increasing by monotone feasibility, so Chebyshev's inequality yields

$$\frac{1}{n}\sum_{i=1}^{n} i\, G(i) \;\geq\; \Big(\frac{1}{n}\sum_{i=1}^{n} i\Big)\Big(\frac{1}{n}\sum_{i=1}^{n} G(i)\Big) = \frac{n+1}{2}\,\frac{1}{n}\sum_{i=1}^{n} G(i).$$

Multiplying both sides by n gives

$$\sum_{i=1}^{n} i\, G(i) \;\geq\; \frac{n+1}{2}\sum_{i=1}^{n} G(i).$$

Substituting this into the decomposition of the left-hand side of (1) yields

$$\sum_{i=1}^{n} \big[2i - (n-1)\big]\, G(i) \;\geq\; 2\,\frac{n+1}{2}\sum_{i=1}^{n} G(i) \; - \; (n-1)\sum_{i=1}^{n} G(i) = 2\sum_{i=1}^{n} G(i).$$

Finally, because at least one $G(i)$ is strictly positive under our productivity assumption, the sum $\sum_{i=1}^{n} G(i)$ is strictly positive and hence the entire expression is strictly greater than zero. This establishes (1) and therefore proves Proposition 5.

B General-equilibrium foundations for Proposition 1

This section shows that the entrepreneurial formation–then–sale result of Proposition 1 is not an artefact of the functional forms used in the baseline model. We place the argument in a general, Arrow–Debreu environment and describe conditions under which the unique rational expectations equilibrium has (i) firms founded by agents who will be essential inside the firm, and (ii) assets subsequently owned by outsiders by the time production takes place. Our only special assumption is the use of Shapley bargaining to divide the surplus generated within a firm; otherwise, we impose no particular functional forms on preferences, technologies or the joint output of firms. The construction parallels the argument in Section 3 of the paper but shows that the main result is generic in a large class of general equilibrium economies.

B.1 Environment

There is a finite set of commodities and a finite set of agents. Each agent has a convex, continuous and locally non–satiable preference relation over commodity bundles. All markets are competitive, and there are no agency frictions outside of the intra–firm bargaining problem described below. Time is discrete, and there are three stages: asset formation, asset trading/bargaining, and production/consumption.

Self–production. At stage 0 agents supply labour or other inputs to a self–production technology. Let w denote the vector of competitive wages required to clear this market. We assume the self–production technology is strictly convex and yields a positive finite supply at every finite wage vector, so that the standard existence of equilibrium in the Arrow–Debreu economy ensures well–defined wages.

Firm templates and specific assets. There is a countable family $\mathcal{T}$ of firm "templates". A template $t \in \mathcal{T}$ is described by the tuple (y_t, m_t, k_t) where $y_t \in \mathbb{R}_+$ is the joint output in numeraire units, $m_t \in \mathbb{N}$ is the number of essential agents required to operate the firm, and $k_t \in \mathbb{R}_+$ is the cost of creating one specific asset of this type. A specific asset of type t yields output *only if* it is combined ex post with exactly m_t agents in distinct essential roles; otherwise, its output is zero. A single agent cannot fill more than one essential role in a given firm.

Asset formation (stage 0). Any agent can pay k_t units of the numeraire to create one asset of type t. We call an agent who creates an asset a "founder." If an asset is created, the founder initially owns it. Asset creation is subject to free entry, and agents are price takers in the asset market.

Asset trading and bargaining (stage 1). After observing the wages w and the set of created assets, agents trade assets in a competitive asset market. Trading is frictionless: any asset may be sold at the unique market price. Simultaneously, for each asset, the m_t essential agents and the current owner engage in bargaining to divide the surplus generated by the firm. We assume that the surplus—output minus outside options—is divided according to the Shapley value of the cooperative game in which the asset owner and each essential agent are players, and the characteristic function gives zero to any coalition that does not contain the asset and all essential roles and y_t to the coalition containing the asset and all m_t essential agents. Formally, letting w_j denote the outside wage of essential agent j and $S_t(w) \equiv y_t - \sum_{j=1}^{m_t} w_j$ denote the net surplus of template t at wage w, the Shapley payoff vector $\left(\pi_j^{\mathrm{M}}, \pi^{\mathrm{O}}\right)$ assigns to each essential agent j and owner the following shares:

$$\text{(outside ownership)} \quad \pi^{\mathrm{O}} = \frac{S_t(w)}{m_t+1}, \qquad \pi_j^{\mathrm{M}} = w_j + \frac{S_t(w)}{m_t+1} \quad \text{for each essential } j;$$
$$\text{(manager ownership)} \quad \pi_j^{\mathrm{M}} = w_j + S_t(w)/k_t \quad \text{for each essential } j, \quad \pi^{\mathrm{O}} = 0.$$

These formulas are standard results for the Shapley value of a surplus generated by a set of m_t essential agents and one non–human asset.

Production and consumption (stage 2). After asset ownership is determined and wages are agreed upon, production occurs: each firm generates y_t units of the numeraire if and only if the asset is owned and all m_t essential roles are filled. Agents consume the numeraire according to their preferences. We assume that the numeraire and any other commodities are priced competitively and markets clear.

B.2 Existence and characterisation of equilibrium

We define a *rational–expectations competitive equilibrium (RECE)* for this economy as a wage vector w, an asset–formation decision (i.e. how many assets of each type are created), a pattern of asset ownership, and assignments of agents to essential roles such that: (i) self–production supply clears at wage w; (ii) asset trading and Shapley bargaining shares are mutually consistent and competitively valued; (iii) consumption/production allocations maximise agents' utilities at market prices; and (iv) free entry ensures that no agent can earn a strictly positive expected profit by creating an additional asset of any type.

We now state and prove the general analogue of Proposition 1.

Proposition 6 (Founders and outside ownership in RECE) *Consider the environment above. Suppose there exists a type $t \in \mathcal{T}$ such that its net surplus $S_t(w) = y_t - \sum_{j=1}^{m_t} w_j$ is strictly positive at equilibrium wages w. Then, in any RECE in which assets of type t are active:*

(i) Any active asset of type t is created by an agent who will occupy one of the m_t essential roles (i.e. a future manager);

(ii) Before production, the asset is traded to an outside owner and the sale price is $\frac{S_t(w)}{m_t+1}$, which equals the outsider's Shapley rent; and

(iii) The free–entry condition implies that the manager/founder's expected net return (sale price plus Shapley rent minus creation cost) equals zero, while the outsider's net return is zero because asset prices are bid up to their expected profit.

Proof. Fix a type t with $S_t(w) > 0$. First, observe that if an asset is created and remains owned by an essential agent ("manager ownership"), then each essential agent receives y_t/m_t from Shapley bargaining. The manager's willingness to sell is therefore $\pi_m^{\text{M}} - w_m = \frac{y_t}{m_t} - w_m$. Conversely, if an asset of type t is owned by an outsider, the outsider's Shapley rental payoff is $\pi^{\text{O}} = S_t(w)/(m_t+1)$ and each essential agent receives $w_j + S_t(w)/(m_t+1)$. The manager's willingness to pay for an owned asset is thus their Shapley payoff as manager minus the wage they would receive if the asset were owned by an outsider, that is,

$$w_m + S_t(w)/k_t - \left[w_m + \frac{S_t(w)}{m_t+1}\right] = \frac{S_t(w)}{m_t(m_t+1)}.$$

Since $S_t(w) > 0$ by assumption, the outsider's willingness to pay $S_t(w)/(m_t+1)$ strictly exceeds the manager's willingness to pay $S_t(w)/(m_t(m_t+1))$. Thus, if an asset is initially owned by an insider, it will be sold to an outsider before production; if it is initially owned by an outsider, the outsider will retain it. Hence (ii) holds.

Turning to entry, compare the expected net payoffs from creating one asset. A pure outsider founder would capture at most their Shapley share $S_t(w)/(m_t+1)$ and then pay the creation cost k_t. Anticipating the competitive asset market, the net return to an outsider founder is $S_t(w)/(m_t+1) - k_t$. A manager founder, however, captures both the sale price $S_t(w)/(m_t+1)$ and their post–sale Shapley rent $S_t(w)/(m_t+1)$; their net return is $2S_t(w)/(m_t+1) - k_t$. Because $S_t(w) > 0$, the latter strictly dominates the former. Free entry implies that managers create assets of type t until their expected net return is driven to zero: $2S_t(w)/(m_t + 1) - k_t = 0$. Meanwhile, outsiders' net returns are zero because asset prices equal expected profits in the competitive market. These observations establish (i) and (iii).

Finally, standard arguments in general equilibrium theory (e.g. Arrow–Debreu existence) guarantee that a fixed point exists for the wage vector w consistent with (i)–(iii) and market clearing. Because the self–production sector and agents' preferences are continuous, the function mapping w to net surplus and hence to asset creation is continuous and monotone. Tarski's fixed–point theorem or Kakutani's fixed–point theorem then yields the existence of a RECE with the stated properties. The equilibrium derived in Proposition 1 of the paper corresponds to the special case $m_t = 2$, $y_t = y$ and $k_t = 1$ with two essential skills and the self–production supply curve given in Section 2.2, but the conclusion of the proposition holds in the much more general environment specified above. ■

Discussion

Proposition 6 demonstrates that the qualitative mechanism behind Proposition 1—managers form firms and then sell them to outsiders—is robust to the particular functional forms used in the baseline model. It depends only on (a) the specificity of the asset, so that insiders' outside options matter for the surplus; (b) competitive asset markets, which eliminate outsider rents; and (c) Shapley bargaining, which ties each agent's bargaining power to their essentiality. As stressed in the main text, non-contractible improvements in output that require manager ownership or fungibility of capital can overturn the result; however, the general equilibrium logic underlying Proposition 1 persists across a large class of economies.

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