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Trust, Collaboration, and Economic Growth

Jiro Kondo,[a] Danielle Li,[b,c] Dimitris Papanikolaou[c,d]

[a] Desautels Faculty of Management, McGill University, Montreal, Quebec H3A 1G5, Canada; [b] Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts 02142; [c] National Bureau of Economic Research, Cambridge, Massachusetts 02139; [d] Department of Finance, Kellogg School of Management, Evanston, Illinois

*Corresponding author

Contact: jiro.kondo@mcgill.ca, https://orcid.org/0000-0002-0352-7700 (JK); (DL); d-papanikolaou@kellogg.northwestern.edu, https://orcid.org/0000-0002-4337-5705 (DP)

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Abstract. We propose a macroeconomic model in which variation in the level of trust leads to higher innovation, investment, and productivity growth. The key feature in the model is a hold-up friction in the creation of new capital. Innovators generate ideas but are inefficient at implementing them into productive capital on their own. Firms can help innovators implement their ideas efficiently but cannot ex ante commit to compensating them appropriately. Rather, firms are disciplined only by the value of their reputations—the present value of their future partnerships. We model trust as a public signal and construct a correlated equilibrium. When trust is high, firms anticipate fruitful collaborations and thus can credibly commit to not expropriating inventors, leading to the more efficient production of new capital. Our model can be used to qualitatively replicate the empirical relation between measures of trust and investment, innovation, and productivity growth—at both the micro and macro level.

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Keywords: trust • economic growth • investment

1. Introduction

Some countries grow at a much faster rate than others, even over long periods of time. The fact that persistent differences in economic growth are associated with differences in investment-to-output ratios (De Long and Summers 1991) suggests that variation in the marginal efficiency of investment may be a key driver of cross-country differences in growth rates. This shifts the question then to understanding why the marginal returns to investment may vary across countries. Such persistent differences in the marginal returns to investment are unlikely to arise purely because of differences in technology—because the diffusion of technology globally would need to be quite limited to explain such persistent differences. This view has led to the rise of alternative factors—such as institutions, social capital, or the level of trust—to explain persistent differences in growth rates across countries (Acemoglu et al. 2005). However, despite voluminous empirical evidence documenting the association between measures of social capital or trust and economic growth (Guiso et al. 2006), the theoretical link remains underdeveloped.

We provide a tractable general equilibrium model that illustrates how variation in the level of trust—defined as the ability to sustain relational contracts—affects the marginal return to investment and therefore future economic growth. Our starting point is that the process of creating new capital requires not only physical inputs but also ideas (investment opportunities). These ideas originate with innovators, who typically lack the resources to implement them efficiently on their own. However, by collaborating with firms, they can access more resources and thus implement their ideas more efficiently. Although partnerships may be more efficient, they expose innovators to the risk of expropriation. That is, once the firm is aware of the inventor's idea, it can choose to honor the terms of their agreement or refuse to compensate her for the value of her idea. Hence, the market for ideas is incomplete, as in Arrow (1962).[1] If innovators worry that they may be expropriated, they will choose to inefficiently implement their ideas on their own.

Reputational concerns can discipline firms and limit expropriation. Specifically, firms will interact with future innovators, and expropriation is observable. In deciding whether to expropriate the innovator or not, the firm trades off the immediate benefit of refusing to pay the innovator her fair share with the loss of its reputation. The loss of a firm's reputation—and therefore its future partnership opportunities—can, in some cases, serve as a deterrent. In particular, firms can credibly commit to not stealing a given idea if they value their future partnerships more than their gains from expropriation today. This means that the better an idea is, the less firms are able to credibly commit to not stealing. Anticipating this, inventors will collaborate with firms on their lower-quality ideas but will inefficiently implement their best ideas on their own. That said, our model clearly has multiple equilibria. Even in cases where there exists a partially cooperative equilibrium, as described above, there always exist noncooperative equilibria: if all inventors decide never to trust firms, then the value of firms' reputation is zero, and they would always expropriate inventors.

Our notion of a high degree of trust is that it allows agents to coordinate their actions toward the collaborative equilibrium. In particular, we model the level of trust in the economy as a public signal and construct a correlated equilibrium in the spirit of Aumann (1987). When the level of trust is low, innovators never enter into any partnerships, anticipating that they will be always expropriated by firms. As a result, new ideas are always implemented inefficiently, and the marginal return to investment is low. By contrast, when the level of trust in the economy is high, innovators are willing to (partly) collaborate with firms. Because a higher fraction of ideas is implemented efficiently than in the low-trust regime, the marginal efficiency of investment is higher.

In brief, variation in the level of trust impacts both innovators' willingness to collaborate and the value of firms' reputations. To draw the link between trust and economic growth, we embed this mechanism into an otherwise standard real business cycle model. When aggregated, the level of trust directly affects the marginal returns to investment in new capital. In all other respects, our model is similar to a standard macro model in which the marginal efficiency of investment varies over time. In the model, an increase in the level of trust leads to higher output and productivity growth, as well as a higher investment-to-output ratio.

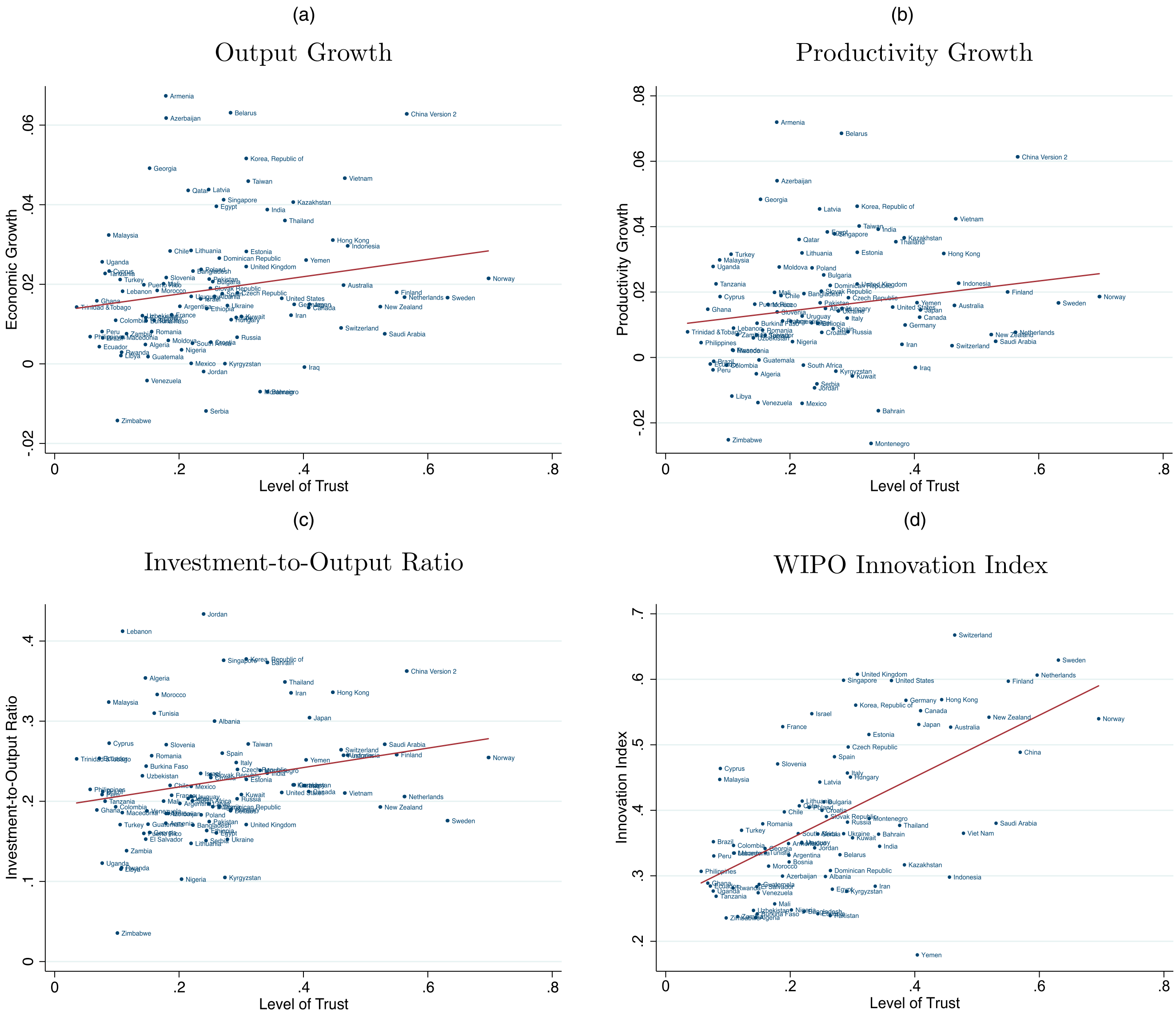
Our model can help shed light to the empirical relation between trust and growth. Viewed through the lens of the model, a country can be interpreted as a separate model economy with its own level of trust. As a result, our model can replicate the em pirical relation between persistent differences in measures of trust and subsequent economic growth and investment-to-output ratios at the aggregate level (see, e.g., Knack and Keefer 1997, Hall and Jones 1999, Guiso et al. 2006, Algan and Cahuc 2010, Tabellini 2010). In addition, we consider an extension of the model in which firms vary in their level in which they inspire trust to innovators. The extended model generates a cross-sectional relation between measures of trust and innovation outcomes within the same economy. This prediction is consistent with recent work by Nguyen (2019), who documents that shifts in the level of management-employee trust are related to measures of innovation outcomes at the firm level.

In sum, our main contribution is to provide a tractable general equilibrium model that embeds some of the insights from the voluminous literature on trust and economic growth. Indeed, the role of trust, culture, and social capital in shaping economic and social outcomes has long been a subject of study among political philosophers, and in political science and sociology (e.g., Weber 1905, Banfield 1958, Gramsci 1971, Gambetta 1988, Putnam et al. 1994, Fukuyama 1995). More recently, a large empirical literature in economics has documented a robust positive relation among social capital, cooperation, and economic output (for surveys, see La Porta and Vishny 1997, Guiso et al. 2006, Algan and Cahuc 2013, Bjornskov 2017). Newer studies, in fact, provide evidence of a causal link between trust and economic development; Tabellini (2010), for instance, showed that historically contingent variation in measures of culture within Europe leads to substantial differences in present economic conditions, along the lines posited by Putnam et al. (1994). Algan and Cahuc (2010) showed that differences in trust inherited by descendants of immigrant populations predict present day income.

Our work contributes to a smaller literature that provides a theoretical justification for the empirical links between trust and growth. Specifically, Akcomak and ter Weel (2009) provided an endogenous growth model in which social capital enters directly the production of ideas. Zak and Knack (2001) endogenized trust as a function of social heterogeneity; similar to ours, their model also implies that high levels of trust lead to higher investment. Doepke and Zilibotti (2014) considered the generational transmission of preference parameters—patience and risk tolerance. Our model differs from much of this work because we view trust as mitigating an incomplete contracting problem rather than as a preference parameter or direct input into production. Francois and Zabojnik (2005) considered a model with hold-up that bears similarities to ours but focuses on the intergenerational transmission of trust as an outcome rather than as an explanation for growth. Perhaps closest to our work is Francois and Roberts (2003), who viewed trust as mitigating incomplete contracts and leading to higher provision of effort by workers in production. Our mechanism is, however, distinct: we focus on innovation—rather than worker effort—as the main channel.

Our choice to focus on innovation is primarily motivated by the frictions in implementing new ideas into productive units of capital. That is, innovation decisions are notoriously difficult to contract on because outcomes are uncertain and ideas, once communicated, can be easily stolen (Arrow 1962; Anton and Yao 1994, 2002; Hellmann and Perotti 2011). It is natural, then, to suspect that trust and relational contracting play an important role in enabling and

Figure 1. (Color online) Country-Level Trust and Economic Growth

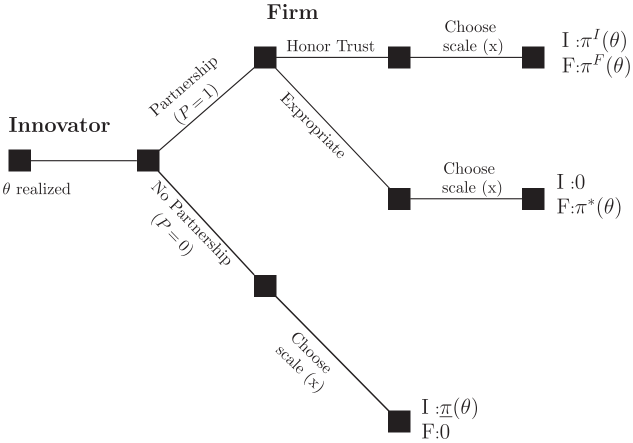


Notes. The scatter plots correspond to the cross-country regressions in Table 1, specifically columns (3), (5), (7), and (8). The independent variable (trust) comes from the World Values Survey, specifically, the response to question A165 "Most people can be trusted." We code affirmative responses a 1 and negative responses as 0. The dependent variables for (a) through (c) come from Penn World Tables: Investment-to-Output: investment share of GDP (variable *ki*); economic growth is the average growth in log GDP per capita (variable *rgdpeqa*); and growth in labor productivity is the average growth in log GDP per worker (variable *rgdpwok*), respectively. The dependent variable in (e) is the Global Innovation Index published by the World Intellectual Property Organization (WIPO).

sustaining innovative partnerships. Rather than considering explicit contracts, our focus is on relational contracts. That is, in our model, inventors and firms play a repeated version of the Trust game as in Camerer and Weigelt (1988) and Berg et al. (1995). A shift in the level of trust leads to more efficient implementation of ideas. Our work also contributes to the literature studying the role of frictions in entrepreneurship, in the context of real business cycle (RBC)-style models (see, e.g., Silveira and Wright 2010, Chiu et al. 2011). Last, our main mechanism that leads to inefficient implementation of the best ideas is closely related to Kondo and Papanikolaou (2015), who apply a version of the same mechanism to models of limited arbitrage.

Our model predicts that variation in the level of trust leads to variation in the marginal return to investment and research and development (R&D) spending. Hence, one interpretation of the model is that it provides a microfoundation for variation in the marginal efficiency of investment—either across countries or firms at a given point in time or focusing on changes within a country or firm over time. That said, our theory is not the only possible microfoundation. For example, in the models of Bernanke and Gertler (1989) and

Figure 2. Capital Creation: The Trust Game



Carlstrom and Fuerst (1997), shocks to entrepreneurial net worth or shifts in the parameters governing the agency friction will affect the rate at which consumption goods are transformed into investment. In the model of Ai et al. (2012), variations in the stock of intangible capital will also affect the relative price of investment goods. However, none of these papers explicitly spell out the connection of shocks to the marginal efficiency of investment. Our mechanism is also related to models with financial constraints. Also related to our paper is the work of Jermann and Quadrini (2007) and Chen and Song (2013), who showed that in the presence of a standard financial friction—a collateral constraint—good news about the future can generate an economic expansion today.

Last, our model provides a possible economic foundation for the existence of venture capital (VC) cycles (Gompers and Lerner 2006). Applied to the VC setting, an increase in trust raises the value of a VC's future partnerships, thereby allowing them to credibly commit to treating entrepreneurs well. The result is that more startups will be funded and—importantly—their average quality should increase, because entrepreneurs are now more willing to trust partners with their best ideas. These predictions are borne out empirically: Nanda and Rhodes-Kropf (2013), for instance, showed that (conditional on going public) startups funded in very active VC periods were better as measured by their number and quality of patents and their valuation at initial public offering (IPO).

2. Motivating Evidence

Here, we revisit the empirical relation between measures of trust and economic growth (see, e.g., Guiso et al. 2006, for a survey of existing evidence). We first reproduce and extend the existing cross-country correlations between measures of social trust gathered from the World Values Survey and country-level outcomes. We focus on outcome variables that closely follow from the predictions of our model: we consider measures of economic growth (output and productivity) and the ratio of investment-to-output. In addition, we also examine an index of innovation published by the World Intellectual Property Organization (WIPO).

In Figure 1 (a) and (b), we document correlations between country-level trust and economic growth; the accompanying regressions are presented in the odd columns of Table 1. Here, trust is measured from the World Values Survey (WVS) as the proportion of respondents who agree with the statement "Most people can be trusted." In Figure 1(a), we document a positive relation between trust and the average growth rate of gross domestic product (GDP) per capita—where output per capita is measured from the Penn World Tables and the average growth rate is computed over the years in which the country appears in the WVS. Moving from the 25th percentile of trust (in which 15% of respondents believe that most people can be trusted) to the 75th percentile (in which 33% agree) is associated with a 0.3-percentage-point increase in the average growth in output per capita. Figure 1(b) documents a similarly strong relationship between trust and labor productivity growth: moving from the 25th to the 75th percentiles of trust is associated with a 0.4-percentage-point increase in productivity growth.

In Figure 1(c), we find a strong correlation between measures of trust and the ratio of investment to output. Moving from the 25th to the 75th percentiles of trust is associated with a 2.2-percentage-point or approximately 10% higher investment ratio. Last, Figure 1(d) shows a strong correlation between measures of trust and innovation—measured using the Global Innovation Index published by WIPO, which takes values in the range of 0 to 1. We see that moving from the 25th to the 75th percentiles of trust is associated with a 0.083 increase in the index, which is approximately one-half of its interquartile range (0.17).

The strong correlation between trust and measures of investment and innovation that we document are consistent with the spirit of our model—that higher levels of trust allow for more efficient implementation of ideas. Naturally, countries differ on many unobservables, so our cross-country comparison is primarily suggestive. To provide further evidence consistent with a link between trust and measures of innovation, we perform a within-country analysis, exploiting heterogeneity across firms.

We document correlations between firm-level measures of trust and firm-level measures of both patenting output and innovator mobility. We use firm-level measures of trust from Sull (2018), who compiled a data set of employee sentiment. To construct a measure of firm-level trust, Sull (2018) examined the text of more than one million online employee reviews of public firms on Glassdoor.com from 2014 to 2018. Our measure of firm level trust is comprised of an incidence

Table 1. Country-Level Trust, Investment, Economic Growth, and Productivity

	GDP P.C.		Inv. Share		Output P.C. Growth		TFP Growth		Innovation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Level of trust	3.222***	3.268***	0.121**	0.118**	0.0218**	0.0243**	0.0229*	0.0263**	0.4714***
	(0.740)	(0.750)	(0.0477)	(0.0490)	(0.0107)	(0.0103)	(0.0119)	(0.0115)	(0.0662)
Level	Cross	Panel	Cross	Panel	Cross	Panel	Cross	Panel	Cross
Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No
R^2	0.161	0.182	0.058	0.064	0.035	0.076	0.030	0.070	0.336
Observations	95	2,615	95	2,615	95	2,520	95	2,511	90

Notes. The independent variable (trust) comes from the World Values Survey, specifically, the response to question A165 "Most people can be trusted." We code affirmative responses a 1 and negative responses as 0. Depending on the specification, we take a within-country average (odd columns) or country-period average (even columns). The first set of dependent variables come from Penn World Tables: Investment-to-Output is the investment share of GDP (variable *ki*); growth in output per capita is the average growth in log GDP per capita (variable *rgdpeqa*); and growth in labor productivity is the average growth in log GDP per worker (variable *rgdpwok*). The last dependent variable is the Global Innovation Index published by the World Intellectual Property Organization (WIPO). In the odd columns, we run cross-sectional regressions of country level averages. In the even columns, we estimate a panel specification, in which the independent variable is trust measured over a given survey wave, and the dependent variable is the average investment to output, growth in output, or labor productivity over the next 5 years following the last year of the survey; the specification includes period (i.e., survey wave fixed effects). We report *t*-statistics in parentheses; standard errors are computed as in White (1980).

***,**, and *Significance at the 1%, 5%, and 10% levels, respectively.

component, which measures how often concepts related to trust show up in freeform employee reviews, and a sentiment component, which measures whether the review emphasizes a positive view of trust within the firm or a negative one. We multiply these two components and then standardize the resulting variable.

Given this measure of trust, we link firms to data on a variety of innovation-related outcomes. First, using data from the United States Patent and Trademark Office's (USPTO's) PatentsView database, we consider patenting outcomes for a given firm in a given year. We measure patenting output in several ways: the total number of patents and the number of patents that are high impact, as measured by whether they have forward citations in the top 90th or 75th percentiles of their patent class and grant year cohort. We obtain additional data on firm financials from Compustat.

Table 2 examines the correlation between our measure of firm-level trust and innovation outcomes. The underlying data consists of patenting across 146 firms over the period 1985 to 2013. In each plot, we control for firm R&D expenditure, assets, and profits; fixed effects for deciles of the number of inventors a firm has; its number of Glassdoor reviews; and year fixed effects. We cannot control for firm fixed effects because our trust measure is measured at a single point in time. We find strong evidence that trust is correlated with more patents in total, with more highly cited patents and with more financially valuable patents. The magnitudes of these correlations are economically meaningful: a 1 standard deviation (SD) increase in measured trust is associated with an 8% increase in patenting and a 6%–7% increase in the number of highly cited patents. We also report results where we have disaggregated our trust measure into a separate sentiment and incidence component; our results are qualitatively similar and are reported in Table A.1.

Table 2. Firm-Level Trust and Patenting

	(1) Patents	(2) 90 percentile patents	(3) 75 percentile patents
Combined trust	0.079***	0.078***	0.083***
	(0.018)	(0.019)	(0.017)
Full controls	Yes	Yes	Yes
R^2	0.872	0.805	0.845
Observations	3,136	2,805	2,938

Notes. Regressions are at the firm-year level. Full controls include firm R&D expenditure, assets, and profits; the number of inventors a firm has; number of Glassdoor reviews for a firm (fixed effects in deciles of these latter two variables); year fixed effects; and fixed effects for two-digit SIC. Patenting refers to the log of 1 plus the number of patents granted to that firm in a given year; 90th and 75th percentile patenting refers to the log of 1 plus the number of patents in a given firm year that were in the top 90th or 75th percentile of forward citations for patents of the same patent class (CPC)–grant year cohort. Trust is measured as using text analysis of Glassdoor review data, as in Sull (2018). Specifically, combined trust is equal to trust incidence multiplied by trust sentiment, standardized to have mean 0 and SD 1. We report *t*-statistics in parentheses; standard errors are computed as in White (1980).

***Significance at the 1% level.

In our model, trust leads to greater innovative output because firms with higher values of trust are able to partner with inventors with better ideas. The next part of our empirical analysis examines whether this prediction is borne out in the data by examining the relationship between firm-level trust and several measures of inventor quality and inventor mobility. To do this, we link data on individual inventors to patent assignees, again using PatentsView. First, we create measures of inventor quality based on an inventor's total patenting output or the total number of forward citations associated with his or her total patents. We assess the quality of inventors at a firm using the mean of this variable. Next, we also consider measures of inventor mobility. Our measures come from those used in Jung (2019), who constructed inventor mobility from data on inventor-assignee links. The procedure of Jung (2019) defines a transition between two firms as occurring when an inventor files a patent with a new assignee firm. As this approach requires at least two years of patenting to define firm transitions, it excludes inventors with only one year of patenting. Once these data are constructed, we construct measures of inventor mobility: the number of inventors who enter and exit a firm in a given year. Last, we combine our measures of inventor quality and mobility to create a measure of the relative quality of exiting inventors, that is, whether inventors who exit are those who are productive or unproductive relative to other inventors employed at that firm in that year. Our model predicts a negative relation between quality of inventors who exit and the firm's overall trust measure.

Figure 3 presents various correlations between trust and inventor quality and mobility. As with the binned scatterplots in Figure 3, each plot includes controls for firm R&D expenditure, assets, and profits; fixed effects for deciles of the number of inventors a firm has; its number of Glassdoor reviews; and year fixed effects. In addition, we also add fixed effects for two-digit Standard Industrial Classification (SIC). Figure 3, (a) and (b), shows that, after controlling for these variables, firms with higher levels of trust on average employ inventors with higher measures of patenting output and quality: a 1 SD increase in trust is associated with a 3% increase in inventor patenting output. Figure 3, (c) and (d), considers the relation between trust and the mobility of inventors. We find that a 1 SD increase in trust decreases inventor exit by 5% and increases inventor entry by 7%. Finally, Figure 3, (e) and (f), shows that higher trust firms are better able to retain their most productive inventors: exiting inventors tend to be drawn more from the lower tail of the firms' talent distribution. A 1 SD increase in trust lowers the average percentile rank (in terms of citations and patents) of exiting inventors by approximately 20 to 25 percentage points. The accompanying estimates are reported in Table 3; Table A.2 reports results separately by trust sentiment and incidence.

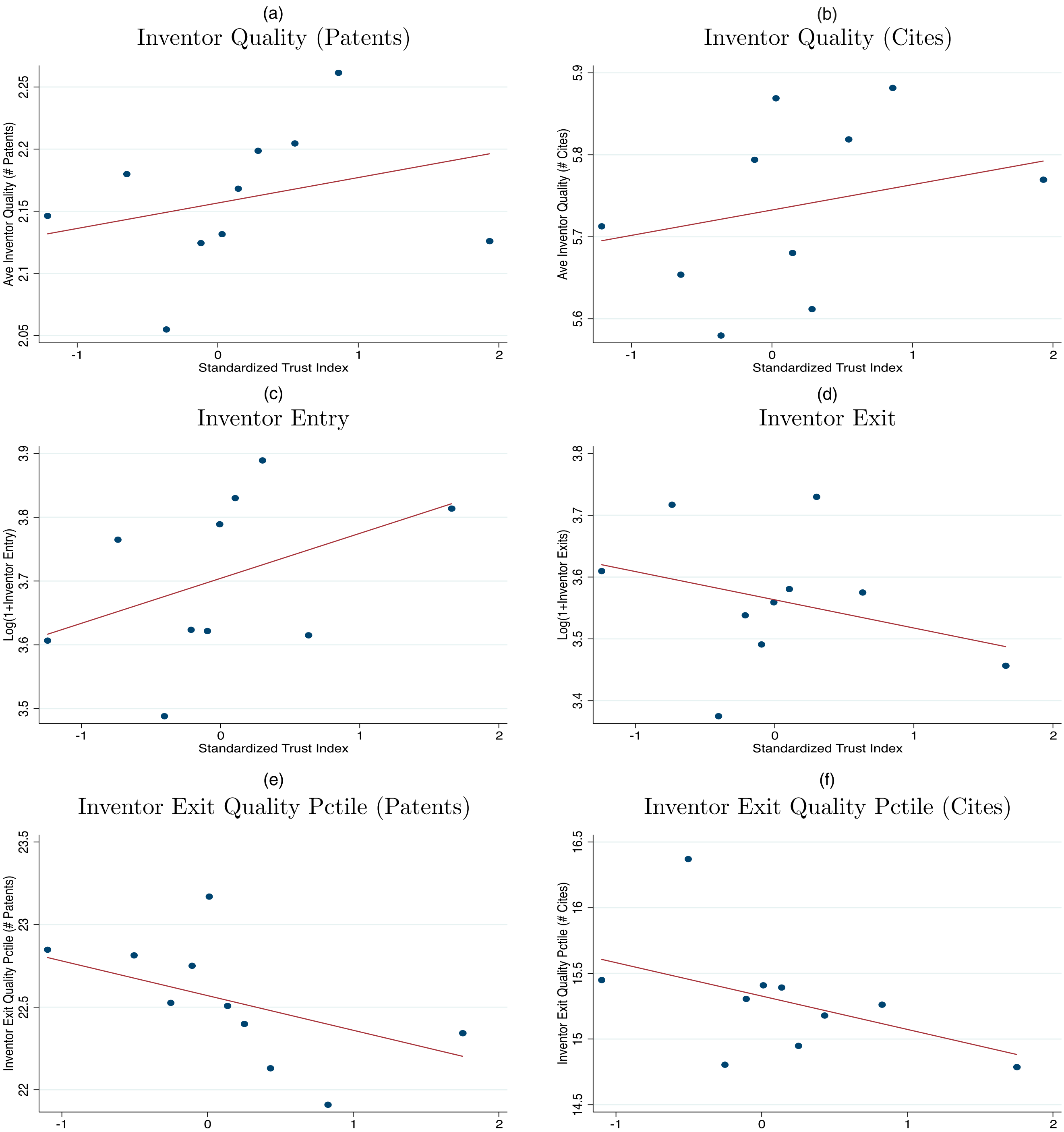
In sum, we see a strong correlation at the country level between trust and the level of investment, innovation, and economic growth. This aggregate relation is supported by firm level evidence: we find that measures of economic trust at the firm level are associated with greater innovative activity—more valuable innovation (as measured by the KPSS index) and a higher number of highly cited patents. Importantly, we also see that firms that score highly in terms of trust attract more and better inventors—which is consistent with the idea that they are more trustworthy partners in a game of collaboration. In the remainder of the paper, we develop a dynamic model that embeds the notion of trust and illustrate the connection with relatively standard real business cycle models.

3. The Model Setup

We next present a model that connects variation in trust and collaboration to variation in the marginal efficiency of investment and economic growth. We consider a continuous-time, infinite horizon economy. Here, an economy can be thought of as a single country or region that may experience shocks to the level of trust. One can think of these shocks as arising, for example, from changes in institutions, laws, or cultural norms over time. At the same time, our model can also be thought of as applying separately to many distinct economies, each with different cross-sectional levels of trust. Viewed in this way, our model can be used to explain the cross-sectional relationships we document in Section 2. In Section 5.4, we consider an extension that allows us to account for firm-level heterogeneity in trust and investment within a single economy.

Our setup borrows the formulation from Kogan et al. (2019), with a few modifications. As in Kogan et al. (2019), households own ideas, and these ideas can be transformed into productive units (projects) when combined with physical inputs (machines). Innovators can share the rents from creating new capital with existing firms. The novel feature of our model is that we introduce a friction in this process: firms cannot commit to pay inventors the full value of their ideas. In our setting, this friction is important: firms can leverage their existing assets, development expertise, or brand name to implement innovators' ideas at a higher level of efficiency than innovators themselves. However, collaboration is only feasible if innovators can trust firms.

Figure 3. (Color online) Firm-Level Trust, Patenting, and Inventor Mobility



Notes. Each panel presents a binned scatterplot of trust on a firm-year level measure of inventor quality and mobility. In each plot, we control for firm R&D expenditure, assets, and profits; the number of inventors a firm has; number of Glassdoor reviews for a firm (fixed effects in deciles of these latter two variables); year fixed effects; and the total number of inventors at the firm. Inventor quality (patents) refers to the log of the total patenting output of an inventor; inventor quality (cites) refers to the log of the total forward citations for the entire patent output of an inventor; inventor entry refers to the log of 1 plus the number of inventors that enter; inventor exit is defined analogously, as in Jung (2019); and Inventor Exit Quality Pctile refers to the within firm-year percentile in patenting output of exiting inventors, measured either by total patents or total citations to all patents. Trust is measured using text analysis of Glassdoor review data, as in Sull (2018).

Table 3. Firm-Level Trust and Inventor Mobility

	(1) Inventor patents	(2) Inventor cites	(3) Inventor exit (log(1 + #))	(4) Inventor entry (log(1 + #))	Inventor exit (quality pctile)	
					(5) Patenting	(6) Cites
Combined trust	0.021**	0.031*	−0.046***	0.071***	−0.210***	−0.254**
	(0.009)	(0.018)	(0.008)	(0.008)	(0.059)	(0.101)
Full controls	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.661	0.616	0.967	0.968	0.626	0.568
Observations	2,119	2,110	3,136	3,136	1,408	1,408

Notes. Regressions are at the firm-year level. Full controls include firm R&D expenditure, assets, and profits; the number of inventors a firm has; number of Glassdoor reviews for a firm (fixed effects in deciles of these latter two variables); year fixed effects; and fixed effects for two-digit SIC. Inventor quality is measured as total patent or citation output; inventor exit refers to the log of 1 plus the number of inventors that exit (controlling for total inventors); inventor entry is defined analogously for inventors who enter, as in Jung (2019); and inventor exit quality percentile refers to the percentile of patenting or citations. Inventor exit quality pctile refers to the within firm-year percentile in patenting output of exiting inventors, measured either by total patents or total citations to all patents. Trust is measured as using text analysis of Glassdoor review data, as in Sull (2018). Specifically, combined trust is equal to trust incidence multiplied by trust sentiment, standardized to have mean 0 and SD 1. We report *t*-statistics in parentheses; standard errors are computed as in White (1980).

***,**, and *Significance at the 1%, 5%, and 10% levels, respectively.

3.1. Households and Production Decisions

3.1.1. Households. There is a continuum of households of measure 1. Households have finite lives; they die with flow probability $\delta^h\,dt$. Households have preferences over future consumption given by

$$U_t = E_t \int_t^{\infty} e^{-\rho(s-t)} \frac{C_s^{1-\gamma}}{1-\gamma}\, ds. \tag{1}$$

The household discounts the future at a rate ρ, which includes the fact that they have finite lives. Each period, households are endowed with a fixed unit of time that they allocate to labor L_t. In Section 5.1 we allow for endogenous labor/leisure choice.

Innovators own ideas (blueprints) that can be used to create new units of capital. Each new household becomes an innovator once—for simplicity, we assume they do so when they enter the economy. An innovating household is endowed with a measure λ/δ^h of identical blueprints. Because households exit at rate δ^h, and exiting households are replaced by new entrants, our assumption implies that the total measure of new blueprints available each period is $\lambda\, dt$.

Each innovator (entering household) has blueprints that are differentiated by a quality level $\theta \in (0,\infty)$, which is independently distributed across inventors according to the cumulative distribution function $F(\theta)$. We assume that the distribution of θ has a finite mean and denote $\bar{\theta} \equiv E[\theta]$. Importantly, the innovator knows the quality θ of her blueprints.

Households belong in a large family or representative household. Our assumption implies that, despite owning claims to ideas of different quality θ, each household consumes the same level of consumption—which is equal to aggregate consumption C_t.[2] We denote the equilibrium state price density by Λ_t, so that the representative household with current wealth given by W_t chooses her consumption C_s to maximize (1) subject to the budget constraint

$$E_t \int_t^{\infty} \Lambda_s\, C_s\, ds = \Lambda_t\, W_t. \tag{2}$$

Equation (2) simply says that the present value of household consumption—discounted using the equilibrium state price density Λ_t—has to equal the total wealth W_t of the representative household.

3.1.2. Production. Ideas can be implemented into production units (projects) that generate a flow of capital services that can be used in production. A project j produces a flow of capital services at time t equal to

$$k_j = a(\theta_j)\, \theta_j^{1-\alpha}\, x_j^{\alpha}, \qquad \alpha \in (0,1). \tag{3}$$

The output of the project is increasing in the quality θ of the blueprint (idea) used in its production and its scale of operation x, which is chosen when the project is created. Here, $a(\theta)$ is a productivity factor that depends on whether the project was created in a partnership between the firm and the inventor (in which case, $a(\theta) = 1$) or by the inventor herself (so, $a(\theta) = \underline{a} < 1$). Last, projects become obsolete with flow probability $\delta\, dt$.

The aggregate flow of capital services produced at time t is equal to the total output of all of the existing projects,

$$K_t = \int_{\mathcal{J}_t} k_j\, dj, \tag{4}$$

where we denote the set of all active projects in the economy by $\mathcal{J}_t$. Similarly, denote by I_t the total investment expenditures, which is equal to the total physical inputs that go into the creation of new projects implemented at time t,

$$I_t = \lambda \int_0^{\infty} x_t^*(\theta)\, dF(\theta). \tag{5}$$

Here, $x_t^*(\theta)$ denotes the optimal scale of a project of quality θ that is implemented at time t.

The representative firm in the final goods sector combines the output of the intermediate good K_t (purchased at price p_t^K) with labor services L (purchased at price w_t) to produce the final good Y_t,

$$Y_t = K_t^{\beta} L_t^{1-\beta}. \tag{6}$$

The final good can be allocated either toward consumption C or toward providing inputs toward the creation of new projects I,

$$C_t + I_t = Y_t. \tag{7}$$

Thus far, we see that the real side of the economy is fairly standard. The model aggregates into a relatively standard neoclassical model (see, e.g., Kogan et al. 2019). The novel part of the paper consists of our modeling the capital creation process as a trust game between two parties: the innovator (trustor) and the firm (trustee). The next section describes this process in more detail.

3.2. Capital Creation as a Trust Game

The innovator has an investment opportunity (idea) that she can implement alone or in partnership with a firm. The presence of decreasing returns to scale to investment implies that these investment opportunities generate profits. Partnering with a firm entails higher efficiency but requires her to place her trust on the firm that she will not be expropriated. Our main assumption is that these parties essentially play a version of the Trust or Investment game (Camerer and Weigelt 1988, Berg et al. 1995).

Innovators are endowed with an investment opportunity of known quality θ. The innovator can implement the investment opportunity without the participation of a firm. In this case, the project generates a flow of capital services given by (3), with $a(\theta) = \underline{a} < 1$. Hence, the innovator can always obtain a positive payoff in the absence of collaboration. We denote by $\underline{\pi}_t(\theta)$ the present value of the payoffs to the inventor from implementing the project herself.

The firm can help the innovator implement the investment opportunity more efficiently. If the inventor and the firm form a partnership, then the project generates a higher flow of capital services, that is, $a(\theta) = 1$. In the case of a partnership, we denote the combined payoff of the two parties by $\pi_t^*(\theta)$. Because collaboration is more efficient, the combined payoff in a partnership exceeds what the innovator can achieve on her own, that is, $\pi_t^*(\theta) > \underline{\pi}_t(\theta)$.

The firm and the inventor can share the surplus from the partnership. We denote by $\pi^I(\theta)$ and $\pi^F(\theta)$ the proposed payoff to the innovator and the firm in a partnership. We will restrict attention to allocation rules that satisfy

$$\pi^I(\theta) + \pi^F(\theta) = \pi^*(\theta). \tag{8}$$

Equation (8) implies that there is no cross-subsidization across current or future innovators.

Although more efficient, a partnership exposes the innovator to the risk of expropriation. The allocation of final payoffs among the two agents is at the discretion of the firm. That is, after the innovator agrees to place her trust on the firm, the firm can choose to honor the original agreement or abuse trust and appropriate the full amount $\pi_t^*(\theta)$ and leave the innovator with a payoff of zero. There is a cost to expropriation, however. Firms are infinitely lived, and therefore will interact with future generations of innovators; most importantly, any abuse of trust is observable.

Figure 1 summarizes the stage game. In brief, the timing of decisions within a period is as follows. The innovator learns the quality θ of her idea and makes a partnership decision $P \in (0, 1)$. If she chooses to collaborate with a firm ($P = 1$), the firm can decide to expropriate the inventor or not. If the inventor chooses not to collaborate ($P = 0$), she can guarantee herself a payoff $\underline{\pi}(\theta)$. After the partnership and expropriation decisions are made, the scale of the project is chosen, and payoffs are realized. Without loss of generality, we can assume that innovators (or firms) can sell their stake in the implemented project; hence, the relevant payoff for their decision is the present value of the associated cashflows.

When contemplating the formation of a partnership, the two parties bargain over the instantaneous surplus. The Nash Bargaining problem can be formulated as

$$\max_{\pi^I(\theta), \pi^F(\theta)} \left(\pi^F(\theta)\right)^{1-\eta} \left(\pi^I(\theta) - \underline{\pi}(\theta)\right)^{\eta}. \tag{9}$$

The solution to (9) is given by

$$\begin{aligned} \pi^I(\theta) &= \bar{\pi}(\theta) + \eta\left(\pi^*(\theta) - \underline{\pi}(\theta)\right) \\ \pi^F(\theta) &= (1-\eta)\left(\pi^*(\theta) - \underline{\pi}(\theta)\right). \end{aligned} \tag{10}$$

For a given level of project quality θ, a partnership is feasible between the innovator and the firm if two conditions are satisfied. First, the innovator needs to obtain a higher payoff under the partnership than her outside option—the value she would realize by im plementing the project alone,

$$\pi^I(\theta) \geq \underline{\pi}(\theta). \tag{11}$$

Given our assumptions on the bargaining process, this constraint is automatically satisfied.

Second, and more importantly, a promise by the firm to pay $\pi^I(\theta)$ to the innovator is only credible if

$$\pi^I(\theta) \leq V, \tag{12}$$

where V is the value of the firm's reputation—specifically, the present value of rents from her interactions with future generations of innovators.

In a partnership with an innovator with an idea of quality θ, firms obtain a payoff $\pi_t^F(\theta)$ in present value terms—which is determined based on the surplus allocation rule in (10). However, firms obtain a payoff $\pi_t^F(\theta)$ only when a partnership occurs, and only a subset of potential ideas is developed in a partnership. As a result, their payoff from an interaction with a single innovator with an idea of unknown quality is given by

$$\overline{\pi}_t^F = \int_0^\infty P_s(\theta)\, \pi_s^F(\theta)\, dF(\theta). \tag{13}$$

Here, $P_t(\theta)$ reflects the inventor's partnership decision and takes the value of 1 if a project of quality θ is undertaken under a partnership at time t, and zero otherwise.

The value of the firm's reputation consists of the present value of all future partnerships, discounted using the equilibrium stochastic discount factor Λ_t. Each instant dt a measure of δ^h inventors is born; each inventor is endowed with λ/δ^h ideas of the same quality θ. Thus, each instant, a measure of $\lambda\, dt$ new ideas are created. Firms are matched to inventors randomly. As a result, each firm faces a probability $\lambda\, dt$ of accessing an investment opportunity each period and obtaining a payoff given by (13). Firms discount the future using the stochastic discount factor Λ_t, which yields the value of their reputation

$$V_t \equiv \int_t^\infty \frac{\Lambda_s}{\Lambda_t}\, \lambda \left(\int_0^\infty P_s(\theta)\, \pi_s^F(\theta)\, dF(\theta)\right) ds. \tag{14}$$

In sum, the value of firms' reputation serves to discipline firms—it imposes constraints on the set of projects that can be feasibly implemented in a partnership in (12). However, this reputation value depends on their future interactions with innovators—that is, the inventors' decision to trust firms $P(\theta)$ affects directly the value of firms' future relationships (14).

3.3. Brief Discussion of Modeling Assumptions

The main assumption of our model is that the market of ideas is incomplete. That is, ideas, once communicated, can be stolen (Arrow 1962). This friction is particularly salient in the creation of new capital—the result of combining ideas (investment opportunities) with physical inputs. Firms likely have an advantage in providing these physical resources; examples include capital, brand value, or expertise in developing ideas into products. As such, most independent innovators must rely on other parties to help realize the full commercial potential of their ideas. However, in communicating the quality of their idea to a potential partner, they run the risk of expropriation. Indeed, intellectual property is difficult to project, and theft can occur even if an idea is patented.[3] The potential for expropriation affects whether an inventor attempts to commercialize an idea on her own or whether she collaborates with an established firm (or venture capitalist).

In our model, collaboration enhances the efficiency of producing new capital—and hence impacts the marginal efficiency of investment. Although the mechanism we outline is potentially more general—and could therefore apply to other sectors in the economy—our modeling choice reflects the view that hold-up frictions are likely to be much greater in the process of creating new capital than, say, in combining existing physical inputs to produce other goods. Although hold-up frictions may exist in the latter setting as well, contracting on physical inputs—selling a machine or performing a certain task—is substantially easier than contracting on ideas.

Our model embeds a dynamic version of the trust game (Camerer and Weigelt 1988) into an otherwise standard real business cycle model. When describing the model, we interpret the trustor as the innovator and the trustee as a firm. Although this interpretation seems natural given our focus on the process of implementing new ideas into productive units, other interpretations are also possible in this setting. For example, the trustee in this arrangement can also be a financier (e.g., a VC) that has expertise in evaluating the project but also the ability to appropriate the idea. Outright idea theft is not the only way that financiers can expropriate innovators; financiers can also appropriate significant rents by diluting the innovator's stake in the venture. Often, this happens after the founder has left the company or been terminated.[4] In addition, sometimes innovators can expropriate firms. According to Bhide (1999), 71% of the founders of firms in the Inc 500 list of fast-growing technology firms report that they replicated or modified ideas encountered through previous employment.[5] Alternatively, the trustee can also be a local or foreign government. For instance, international investors in politically unstable or developing countries face the risk of expropriation of their project investments. Specifically, states can often exercise their sovereignty and appropriate capital, either on an individual basis or as part of a wider scale nationalisation program.[6]

In addition, we have made a number of auxiliary assumptions—mostly for analytical convenience and ease for exposition. First, we assumed that deviations are perfectly observable. Allowing for imperfect observability would increase the benefit from deviation and therefore reduce the set of projects that can be implemented in a partnership; however, our qualitative results would remain unchanged. Second, we restricted innovators to be short lived—or equivalently, to interact with firms only once. This assumption simplifies the dynamic game. More generally, we would have to keep track of multiple sets of continuation values. However, the central insight would survive: an increase in the total continuation value—now to be split among both parties—relaxes the incentive-compatibility constraints in the current period. Third, we assumed that the distribution of θ is unbounded, and the innovator's outside option is strictly increasing in θ. These assumptions imply that expropriation will be profitable for realizations of θ that are sufficiently higher than average, because the relationship value V depends on the average quality of a project. Hence, these assumptions ensure the existence of a finite threshold θ_t^*—so that even in the high-trust regime, not all projects can be implemented in a partnership. Relaxing these assumptions would imply that potentially all projects could be efficiently implemented in the high-trust regime. The resulting dynamics would be somewhat different, but the economy's response to a shift in the level of trust Z_t would be qualitatively similar. Last, we have assumed that households share all risks perfectly. This assumption greatly simplifies the derivation of the stochastic discount factor Λ_t. Relaxing this assumption would imply that households would now have heterogenous consumption profiles (see Kogan et al. 2019 for how to construct Λ_t in this case).

4. Equilibrium

Here, we discuss the equilibrium of the model. To simplify exposition, Section 4.1 starts with the frictionless benchmark. Section 4.2 discusses the equilibrium of the full model with limited commitment. The resulting model has multiple equilibria. Section 4.3 focuses on a particular equilibrium, which involves agents coordinating their actions in response to a public signal—the level of trust in the economy. Section 4.4 explores the response of key economic quantities and prices to an increase in the level of trust.

4.1. The Frictionless Benchmark

Before discussing the full model with limited commitment, it is first helpful to discuss the frictionless case. In this benchmark, all projects are always implemented efficiently (in a partnership), hence $a_t(\theta) = 1$ for all t and θ. Investment is chosen to maximize the value of project,

$$x_t^*(\theta) = \arg\max_x \, q_t\, \theta^{1-\alpha} x^\alpha - x, \tag{15}$$

where q_t is the price of capital, which can be written as the present discounted value of the marginal product of capital—the price of capital services—adjusted for depreciation:

$$q_t = E_t \int_t^\infty e^{-\delta\,(s-t)}\, \frac{\Lambda_s}{\Lambda_t}\, p_s^K\, ds. \tag{16}$$

Our Cobb-Douglas specification implies that the price of capital services is equal to

$$p_t^K = \beta\, K_t^{\beta-1}.$$

Here, K_t refers to the aggregate capital stock, adjusted for quality. The dynamics of the capital stock K_t can be written as

$$dK_t = -\delta\, K_t\, dt + \lambda \left(\int_0^\infty \theta^{1-\alpha}\, x_t^*(\theta)^\alpha dF(\theta) \right) dt. \tag{17}$$

As in the standard model, the aggregate capital stock depreciates at rate δ. The second term in (17) captures the creation of new capital: new projects are created at rate λ, whose scale is chosen optimally in (15). Combining (5) with (15), we get an equation that relates investment expenditures to the price of capital

$$I_t = \lambda\, \bar\theta\, (\alpha q_t)^{\frac{1}{1-\alpha}}. \tag{18}$$

Equation (18) is the analogue of the q-theory of investment in our setting. Combining Equations (15)–(18), we get an expression for the evolution of the capital stock as a function of investment expenditures and the mean project quality $\bar\theta$

$$dK_t = -\delta\, K_t\, dt + I_t^\alpha \left(\lambda\, \bar\theta\right)^{1-\alpha} dt. \tag{19}$$

Examining Equation (19), we see that the frictionless model is essentially isomorphic to the standard neoclassical model with capital adjustment costs. Specifically, there are decreasing returns to investment, captured by $\alpha < 1$. These decreasing returns to investment imply that the capital sector generates profits.

More importantly, we can immediately see the connection with equilibrium models with shocks to the marginal efficiency of investment—or equivalent investment-specific shocks (Solow 1960, Greenwood, Hercowitz, and Krusell 1997, Papanikolaou 2011). In these models, the rate at which current consumption is transformed into installed capital is stochastic and varies with the state of the economy. These shocks can take the form of increased productivity in the sector producing capital goods; shocks entering directly the capital accumulation equation; or shocks to the quality of new capital goods. All of these models reduce to an equation similar to (19), in which the term multiplying investment expenditures I_t is time varying. If we were to extend the model and introduce an exogenous shift in the average quality of new implemented projects—that is, a shock to $\bar{\theta}$, because all projects are implemented—such a shock would also lead to time variation in the marginal efficiency of investment. The resulting model would be isomorphic to a complete-markets version of Kogan et al. (2019). Rather than introducing such a shock, however, in the next section, we will obtain endogenous variation in the marginal efficiency of investment in a model with limited commitment.

4.2. The Model with Limited Commitment

We next discuss the full model, in which firms cannot commit ex ante to not expropriate innovators.

4.2.1. The Partnership Decision. We begin by first computing the payoffs to the inventor and the firm under different nodes of the stage game in Figure 1. In particular, in the case when the project is efficiently implemented, the present value of the benefits from a single project are equal to

$$\pi_t^*(\theta) = \theta\,\pi_0\, q_t^{\frac{1}{1-\alpha}}, \tag{20}$$

where

$$\pi_0 = (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}}. \tag{21}$$

Equation (20) denotes the highest amount of value that can be shared between an inventor and the firm in the event that they form a partnership. By contrast, if the inventor implements the project herself, she can guarantee herself a payoff that is equal to

$$\underline{\pi}_t(\theta) = \theta\,\pi_0\,(\underline{a} q_t)^{\frac{1}{1-\alpha}}. \tag{22}$$

Because $\underline{a} < 1$, we have that $\underline{\pi}_t(\theta) < \pi_t^*(\theta)$ for all t and θ.

The firm's incentive compatibility constraint (12) and our assumption on Nash bargaining (9) impose restrictions on the set of partnerships that are feasible in equilibrium. Specifically, only projects of quality $\theta \le \theta_t^*$ can be implemented in a partnership at time t. To see this, note that Equations (20) and (22) imply that the left side of the incentive compatibility constraint (12) is linearly increasing in θ. By contrast, the right side, which is equal to V, depends only on the average realization of θ. As a result, the partnership rule at time t takes the form

$$\begin{aligned} P_t(\theta) &= 1, \qquad \theta \le \theta_t^* \\ P_t(\theta) &= 0, \qquad \theta > \theta_t^*. \end{aligned} \tag{23}$$

Combining Equations (20) and (22) with (12), we see that the threshold that determines whether a partnership is formed satisfies

$$\theta_t^*\,\pi_0\, q_t^{\frac{1}{1-\alpha}}\left[1 + \eta\left(\underline{a}^{\frac{1}{1-\alpha}} - 1\right)\right] = V_t. \tag{24}$$

Equation (24) is a fixed point problem, because the relationship value to the firm V_t depends on future partnership decisions. Specifically, the value of firms' reputation is the present value of the benefit from meeting future innovators. Upon meeting an innovator at time t, the firm's expected benefit is equal to

$$\overline{\pi}_t^F = \int_0^{\theta_t^*} \pi_t^F(\theta)\, dF(\theta), \tag{25}$$

where the above expression takes into account the fact that firms derive profits only from projects with quality level below the threshold $\theta \le \theta_t^*$. Firms meet inventors with flow probability of $\lambda\, dt$ each period and discount future profits using the stochastic discount factor Λ_t. Consequently, the value of a relationship to the firm is equal to

$$\begin{aligned} V_t &= \int_t^\infty \frac{\Lambda_s}{\Lambda_t}\,\lambda\,\overline{\pi}_s^F\, ds \\ &= \int_t^\infty \frac{\Lambda_s}{\Lambda_t}\,\lambda\left(\int_0^{\theta_s^*} \pi_s^F(\theta)\, dF(\theta)\right) ds. \end{aligned} \tag{26}$$

Equations (24)–(26) summarize the intuition behind the main mechanism in this paper. Relationships are limited in their ability to mitigate the hold-up problem between innovators and firms. Intuitively, the benefits of expropriation to the firm are increasing in the quality of the project θ. By contrast, the costs of expropriation—the loss of future rents (26)—depend on the *average* quality of projects that are supplied to firms. As a result, firms cannot commit to not expropriate an innovator with a sufficiently high-quality project. Innovators anticipate being expropriated and thus refuse to enter a partnership agreement with the firm when their ideas are of sufficiently high quality $\theta \ge \theta_t^*$.

Further, examining Equations (24)–(26), we see that the model admits the possibility of multiple equilibria. For instance, the static Nash equilibrium $(\theta_t^* = 0, V_t = 0)$ is always one of them. In addition to the static Nash equilibrium, there may also exist an equilibrium with the highest levels of collaboration—which is characterized as the one with the highest values of θ_t^* and V_t that solve Equations (22)–(26).

4.2.2. Implications for Aggregate Dynamics. We next examine how the degree of cooperation in the economy—indexed by the threshold θ_t^*—affects aggregate quantities.

Following the same steps that led to Equation (19), we now obtain

$$dK_t = -\delta\, K_t\, dt + I_t^{\alpha}\left(\lambda\, g\left(\theta_t^*\right)\right)^{1-\alpha} dt, \tag{27}$$

where the function $g(x)$ capturing the endogenous return to investment is defined by

$$g(x) \equiv \bar{\theta} - \left(1 - \underline{a}^{\frac{1}{1-\alpha}}\right) \int_x^{\infty} \theta\, dF(\theta). \tag{28}$$

In examining (27), we see that the marginal efficiency of investment is affected by the average quality of ideas. Because of the commitment friction however, not all projects are efficiently implemented. Projects that are below the partnership threshold θ_{t^*} are implemented efficiently; however, ideas that are of sufficiently high quality $\theta \geq \theta_t^*$ are implemented inefficiently. As a result, the *effective* marginal efficiency $g(\theta_t^*)$ is a function of the partnership threshold. The wedge between $\bar{\theta}$ and $g(\theta_t^*)$ depends on the efficiency gains of partnerships relative to stand-alone projects $\underline{a}$, as well as the measure of projects that are implemented efficiently, θ_t^*.

In sum, our model implies that an increase in the partnership threshold θ_t^* has qualitatively the same effect as an improvement in the marginal efficiency of investment. Greater levels of cooperation (an increase in the partnership threshold θ_t^*) lead to more efficient implementation of blueprints, which leads to more installed capital K_t for a given amount of investment I_t. Because the investment decision is endogenous, higher marginal efficiency of investment results in more investment, and because aggregate output is not affected on impact, lower consumption over the short run.

What are the economic forces that would lead to a shift in the partnership threshold θ_t^*? Recall that the basic model features no intrinsic sources of uncertainty; hence, all aggregate quantities are constant once the steady state is reached. In general, however, any shock that affects the cost of expropriation—the value of firms reputation, V_t—will lead to a shift in θ_t^*. Examples of such shocks include the following: shocks to the bargaining power η; preference shocks, such as shocks to the discount rate ρ or risk aversion γ; shocks to the *future* value of projects; or shocks to beliefs about future collaboration. Any one of these shocks will affect the partnership threshold θ_t^* and therefore act as an investment-specific productivity shock. Given our goal of understanding the empirical link between trust and growth, in the next section, we introduce an extrinsic source of uncertainty that serves to coordinate the actions of inventors and firms—we interpret this signal as the level of trust in the economy.

4.3. Equilibrium with Varying Levels of Trust

We next introduce an extrinsic source of uncertainty that can serve as a coordination device. Consider a random variable Z_t, which takes values in $\{0, H\}$; Z_t is persistent and evolves according to a two-state continuous-time Markov chain with an instantaneous transition rate matrix given by

$$T = \begin{pmatrix} -\mu_0 & \mu_0 \\ \mu_H & -\mu_H \end{pmatrix}. \tag{29}$$

That is, if $Z = 0$, then over the next interval dt, the state switches to $Z = H$ with probability $\mu_H\, dt$, and it remains at $Z = 0$ with probability $1 - \mu_H\, dt$. If $Z = H$, over the next interval dt, the state switches to $Z = 0$ with probability $\mu_0\, dt$. Importantly, the current value of Z_t is observable by both parties.

We use this randomization device to construct a correlated equilibrium in the spirit of Aumann (1987). Specifically, we look for an equilibrium in which the innovator places her trust in the firm only if the quality is not too high (as before), but now also only if $Z_t = H$. That is,

$$\begin{aligned} P_t(\theta) &= 1, \qquad \theta \leq \theta_t^H \quad \text{and} \quad Z_t = H \\ P_t(\theta) &= 0, \qquad \text{otherwise}. \end{aligned} \tag{30}$$

Because the level of cooperation now varies with the level of trust (the variable Z_t), the value of collaboration to the firm is also time varying. Specifically,

$$\begin{aligned} V_t^H &= \lambda\, E_t \int_t^{\tau} \frac{\Lambda_s}{\Lambda_t} \left(\int_0^{\theta_s^H} \pi_s^F(\theta)\, dF(\theta) \right) ds \;\; + E_t\left[\frac{\Lambda_\tau}{\Lambda_t} V_\tau^0\right] \\ V_t^0 &= E_t\left[\frac{\Lambda_\tau}{\Lambda_t} V_\tau^H\right], \end{aligned} \tag{31}$$

where τ is a random variable that indicates the next time that the state Z changes.

Dissecting (31), we see that, in the high-trust state, the trustee's value from collaboration depends on the flow of profits during that state, plus her expected discounted continuation value when the state Z switches to the low-trust regime $Z = 0$. In the low-trust regime, the trustee derives zero flow profits (since collaboration does not occur), and her continuation value only depends on the expectation that the state will switch again to a high-trust state.

In the high-trust state, the level of collaboration—the maximal quality of a project that can be implemented in a partnership—is the largest solution to

$$\underbrace{\pi_0\, \theta_t^H\, q_t^{H\frac{1}{1-\alpha}} \left[(\underline{a})^{\frac{1}{1-\alpha}} + \eta \left(1 - (\underline{a})^{\frac{1}{1-\alpha}}\right) \right]}_{\pi_t^I(\theta_t^H)} = V_t^H. \tag{32}$$

Because trust is absent, no collaboration occurs, we can also write $\theta_t^0 = 0$. That is, when $Z_t = 0$, innovators believe that firms will always expropriate them regardless of the value of θ. Hence, they never opt to collaborate with firms.

The equilibrium we have constructed is not unique. We choose to focus on this particular one due the fact it can deliver a theoretical link between fluctuations in the level of trust and the marginal efficiency of investment. Naturally, other equilibria are possible. For instance, one could in principle construct equilibria with additional states for Z_t. We do so explicitly in Section 5.3.

4.4. Response to an Increase in Trust

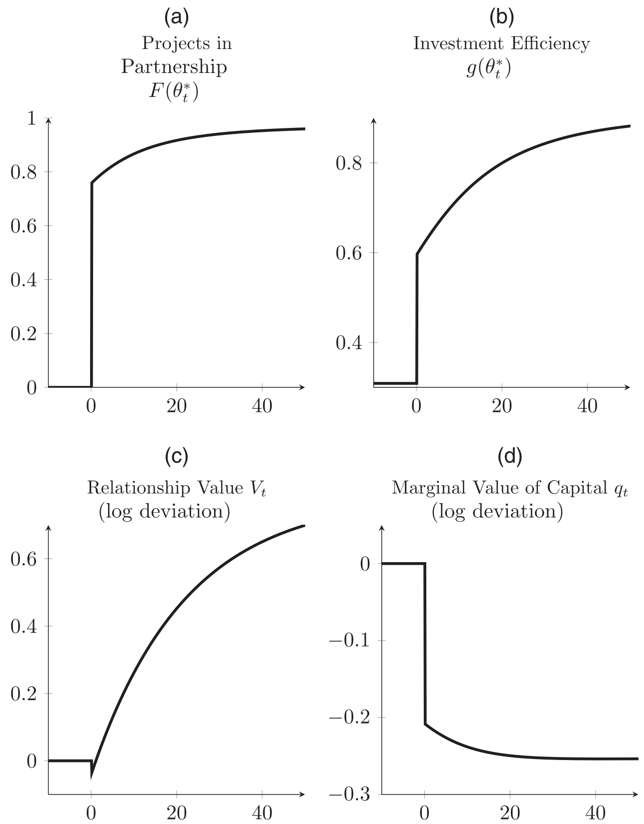
To understand the main mechanism in the model, we next consider how the economy responds to a permanent increase in trust—a shift from $Z_t = 0$ to $Z_t = H$.

4.4.1. Understanding the Mechanism. We first examine the main determinants of the partnership decision in Figure 4. Figure 4(a) shows how the innovator's decision to implement the project in a partnership versus a stand-alone investment responds to a shock to Z. As expected, we see that the measure of projects that are implemented efficiently—as given by $F(\theta_t^*)$—rises on impact. This direct effect follows from our equilibrium construction (30). However, we note there is also an indirect effect, because θ_t^* continues to increase after impact. Figure 4(b) shows the response of the marginal efficiency of investment $g(\theta_t^*)$ to a shock to Z_t. The dynamics response qualitatively mirrors that of the response of the partnership threshold θ_t^*. However, the response is amplified: as the threshold θ_t^* increases, the marginal projects that switch from stand-alone to partnership have increasingly higher productivity. This implies that, for a given increase in θ_t^*, the increase in the marginal efficiency of investment is higher the more projects are already implemented efficiently.

Figure 4, (c) and (d), illustrates how general equilibrium forces lead to a subsequent increase in θ_t^* after impact. Specifically, an increase in the level of cooperation, increases the growth rate of the economy on impact. This increase implies a (temporarily) higher interest rate and a higher level for the capital stock in the long run. The higher interest rate implies that the increase in relationship values (which is a discounted sum of future benefits) rises less than it otherwise would on impact relative to a model with constant interest rates, but increases at a faster rate thereafter. This sustained increase in V_t is, in turn, amplified by the increase in θ_t^* and the fact that firms can appropriate rents from projects with higher quality. Further, just like in models with investment-specific shocks, the price of capital q_t falls. Both of these forces imply both a higher cost and a lower benefit to expropriation, which implies that θ_t^* exhibits a sustained increase after impact.

Figure 5 plots the impulse response of aggregate quantities.

Figure 4. Trust and the Partnership Decision

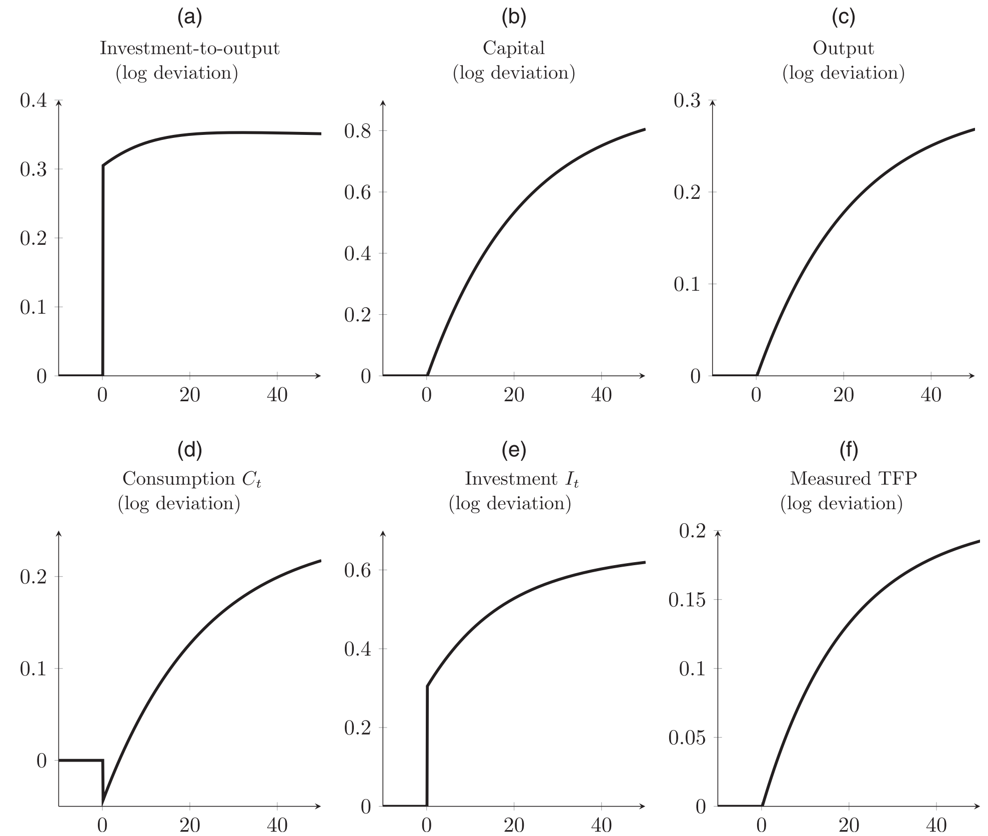


Notes. Figure plots log deviations from the steady state corresponding to $Z_t = 0$ always in response to a permanent increase $Z_t = H$. The figure uses $\rho = 0.01$; $\gamma = 3$; $\beta = 1/3$; $\delta = 0.06$; $\lambda = 0.85$; $\alpha = 0.4$; $\underline{a} = 0.65$; $f(x) = e^{-x}$; and $\eta = 1/2$.

4.4.2. Output, Capital, Investment, and Consumption. Figure 5, (a)–(e), plots the response of capital, output, consumption and investment to an increase in the level of trust Z_t. We see that these responses largely resemble the equilibrium responses to an investment-specific shock (see, e.g., Papanikolaou 2011 for a similar model.). Specifically, an increase in the productivity of investment leads to an increase in the investment-to-output ratio. This increase leads to higher capital accumulation. There is no effect on output Y_t on impact. However, as the economy accumulates more capital, output increases in the medium run. An increase in the efficiency of investment leads to a reallocation of resources from consumption to investment on impact. Hence, investment rises on impact, whereas consumption falls.

Further, by comparing the increase in investment to the increase in output, we can also see that an increase in trust in the model leads to an increase in the investment-to-output ratio. The investment-to-output ratio increases because a permanent increase in the level of trust leads to a permanent increase in the marginal efficiency of investment.

Figure 5. Response to an Increase in Trust



Notes. Figure plots log deviations from the steady state corresponding to $Z_t = 0$ always in response to a permanent increase $Z_t = H$. The figure uses $\rho = 0.01$; $\gamma = 3$; $\beta = 1/3$; $\delta = 0.06$; $\lambda = 0.85$; $\alpha = 0.4$; $\underline{a} = 0.65$; $f(x) = e^{-x}$; and $\eta = 1/2$.

4.4.3. Total Factor Productivity. Figure 5(f) shows that measured total factor productivity (TFP) also increases in response to a positive shock to Z_t. Improvements in the marginal efficiency of investment lead to increases in measured TFP, assuming the capital stock in imperfectly adjusted for quality. Specifically, suppose that the measured capital stock evolves according to

$$d\hat{K}_t = -\delta\, \hat{K}_t\, dt + I_t^{\alpha}\, (\lambda)^{1-\alpha}\, dt. \tag{33}$$

That is, the measured capital stock is constructed by accumulating investment expenses, adjusted for decreasing returns. The difference between (33) and (27) is that the former is not adjusted for variation in the average return to new investments, as captured by $g(\theta_t^*)$.

Under this assumption, we can then compute the measured total factor productivity as the log difference between observed output and the total output implied by (33),

$$tfp_t = \beta\big(\log K_t - \log \hat{K}_t\big). \tag{34}$$

Examining (34), we can see that total factor productivity is a weighted average of past levels of the marginal efficiency of investment $g(\theta_t^*)$.

In sum, we see that the model can generate the empirical correlation between measures of trust and economic growth summarized in Section 2. Both in the data and in the model, variation in trust is associated with higher output and productivity growth, as well as higher investment-to-output ratios. When the aggregate level of trust is high, innovators are more likely to collaborate with firms and hence implement their ideas at a higher level of efficiency—which is also consistent with the empirical correlation between trust and innovation outcomes in Section 2.

5. Extensions

The model we outline above abstracts from many features that are commonly found in business cycle models, for instance, flexible labor supply or variable capital utilization. Stripping down the model to its essential features allows us to see clearly the economic forces in play. In Sections 5.1 and 5.2, we extend the model to allow for flexible labor and capital utilization, respectively—which allow for additional margins of adjustment to the investment/consumption choice. In Section 5.3, we extend the model to allow for additional variation in the level of collaboration—driven by beliefs about the likelihood of trust breaking down in the future. Last, in Section 5.4, we illustrate how one can extend our baseline model to allow for cross-sectional variation in the level of trust within the economy.

5.1. Flexible Labor Supply

Here, we allow for flexible labor supply. We modify the household preferences in (1) to allow for a labor-leisure tradeoff

$$U_t = E_t \int_t^{\infty} e^{-\rho(s-t)} \frac{\left(C_s N_s^{\psi}\right)^{1-\gamma}}{1-\gamma}\, ds, \tag{35}$$

along with a constraint on the total available hours, $L_t + N_t = 1$. Our preference specification follows King et al. (1988). In this case, the supply of labor is determined by the familiar intratemporal first-order condition $U_N/U_C = w_t$, which can be rewritten as

$$L_t = 1 - \psi\, \frac{C_t}{w_t}. \tag{36}$$

Our specification of preferences implies that the income elasticity of labor supply is equal to the opposite of the Frisch elasticity of labor supply.

An increase in trust Z_t increases investment the productivity of investment, and therefore leads to a reallocation of resources from consumption to investment in the short run. As consumption falls, the resulting income effect implies that labor supply increases on impact, as we see in Figure 6(a)–(c). As households become richer—because of the accumulation of capital stock—the wealth effect starts dominating the substitution effect so labor supply declines somewhat from its peak to the new steady state. The fact that the supply of labor increases on impact now implies that aggregate output does so as well, as we see in Figure 6(d). However, despite the increase in output, consumption still declines on impact—partly because of the offsetting wealth and substitution effects—as we see in Figure 6, (e) and (f).

In brief, the model described in this section behaves just like the model with exogenous investment shocks and flexible labor supply analyzed in Papanikolaou (2011).

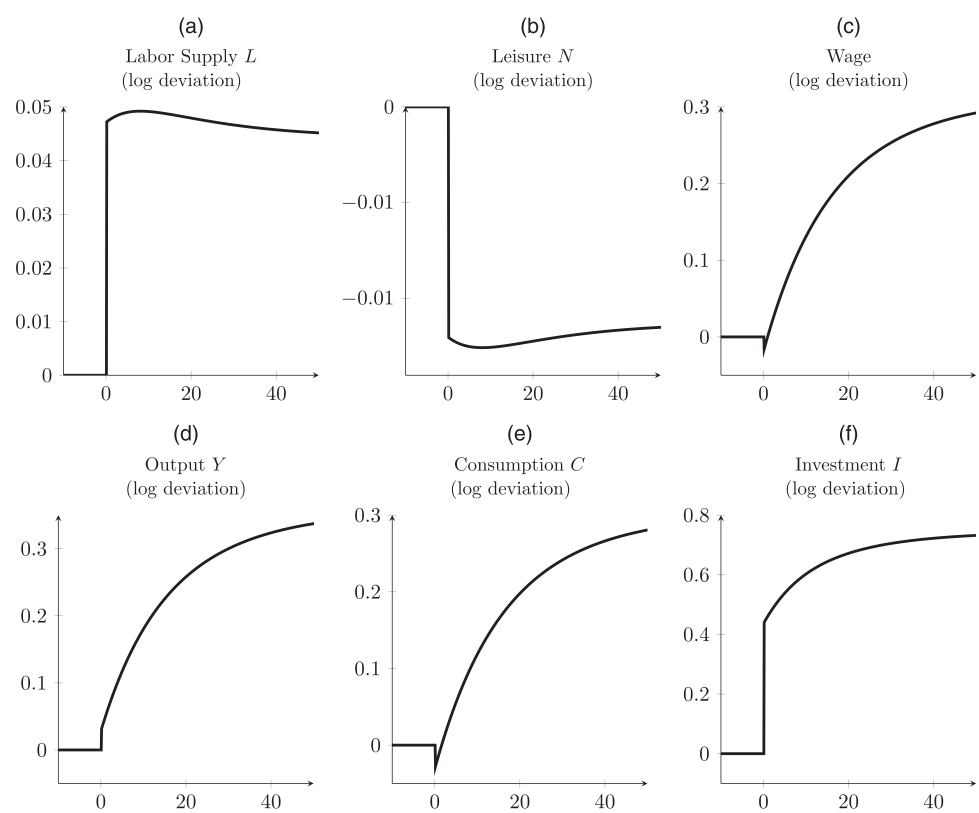
5.2. Variable Capital Utilization

We next allow for flexible utilization of the existing capital stock. Specifically, we now modify the output of a single production unit to equal

$$k_j = u_{j,t}\, a(\theta_j)\, \theta_j^{1-\alpha}\, x_j^{\alpha}, \qquad \alpha \in (0,1), \tag{37}$$

where now the output of the project j is also affected by the rate $u_{j,t}$ at which it is used at time t. A higher rate

Figure 6. Response to an Increase in Trust—Model with Flexible Labor Supply



Notes. Figure plots log deviations from the steady state corresponding to $Z_t = 0$ always in response to a permanent increase $Z_t = H$. The figure uses $\rho = 0.01$; $\gamma = 3$; $\beta = 1/3$; $\delta = 0.06$; $\lambda = 0.85$; $\alpha = 0.4$; $\underline{a} = 0.65$; $f(x) = e^{-x}$; $\eta = 1/2$; and $\psi = 3$.

of capital utilization increases output today but also increases the probability that the project depreciates. Specifically, the probability that the project expires during the period t to $t + dt$ is now a function of the rate of capital utilization $\delta(u)$, which satisfies $\delta'(u) > 0$ and $\delta''(u) > 0$.

The project's variable capital utilization is reflected in the price of capital. That is, we now define the price of capital as inclusive of the optimal capital utilization decision

$$q_t = \max_u E_t \int_t^{\infty} \exp\left(-\int_t^s \delta(u_\tau)\, d\tau\right) \frac{\Lambda_s}{\Lambda_t}\, p_t^K\, u_s\, ds, \quad (38)$$

where p_t^K is the equilibrium price of capital services paid by the final-goods firm. Examining Equation (38), we see that when determining u, firms trade off the benefits of increased capital utilization (which is proportional to the price of capital services) versus the cost (the accelerated depreciation of the installed capital stock).

The first-order condition in this optimization problem can be written as

$$\delta'(u_t) = \frac{p_t^K}{q_t}. \quad (39)$$

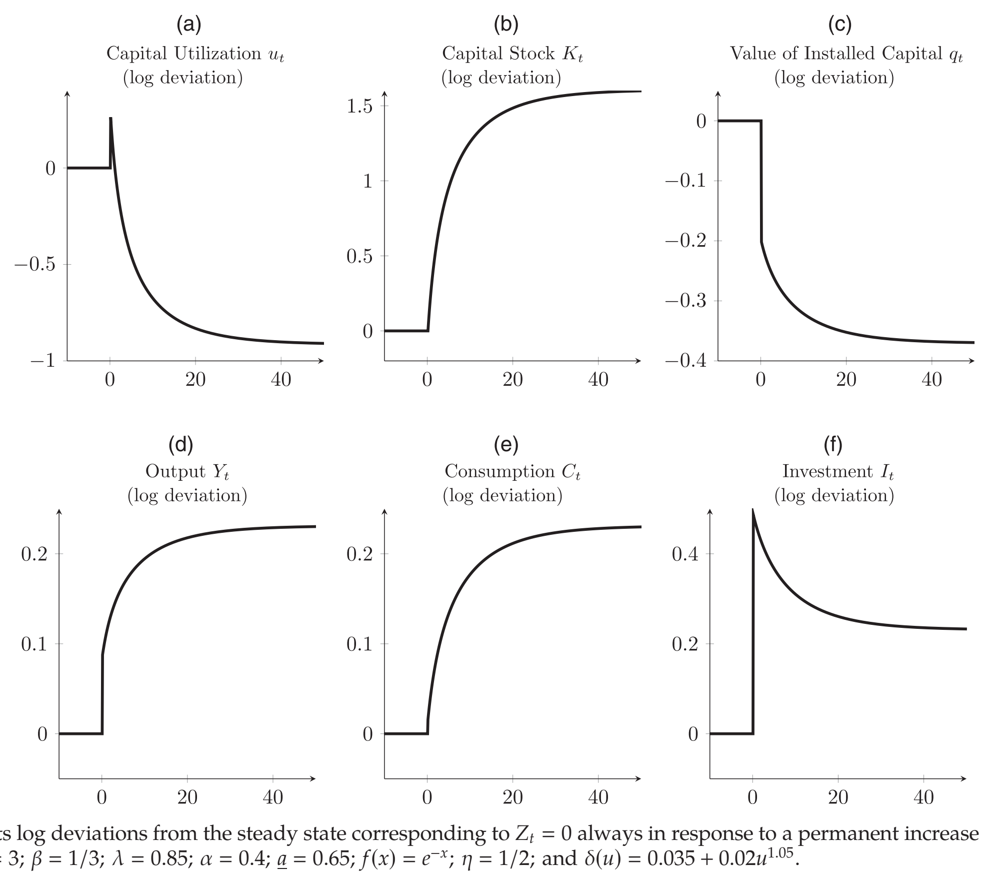
Equation (39) illustrates how the rate of capital utilization depends on the price of capital services p_t^K and the value of installed capital q_t. In equilibrium, the price of capital services satisfies

$$p_t^K\ \bar{u}_t\, K_t = \beta\, Y_t, \quad (40)$$

where $\bar{u}_t$ is the aggregate rate of capital utilization, which firms take as given. Imposing $u_t = \bar{u}_t$ and combining (39) and (40) yield the equilibrium rate of capital utilization. Because the function $\delta(u)$ is convex, the equilibrium utilization rate is decreasing in installed value of capital q_t; consequently, shocks that lower the value of installed capital lead to higher capital utilization. Similarly, an increase in the output-to-capital ratio leads to an increase in the price of capital services and a corresponding increase in capital utilization.

The equilibrium interaction of these forces leads to the dynamic responses we see in Figure 7. Specifically, we see from Figure 7(a) that the equilibrium rate of capital utilization rises in response to a positive shock to Z_t, but then subsequently declines. Figure 7, (b) and (c), shows that the increase of u_t on impact is driven by the fall in the price of installed capital q_t. In the medium run, both the price of capital declines but

Figure 7. Response to an Increase in Trust—Model with Variable Capital Utilization



Notes. Figure plots log deviations from the steady state corresponding to $Z_t = 0$ always in response to a permanent increase $Z_t = H$. The figure uses $\rho = 0.01$; $\gamma = 3$; $\beta = 1/3$; $\lambda = 0.85$; $\alpha = 0.4$; $\underline{a} = 0.65$; $f(x) = e^{-x}$; $\eta = 1/2$; and $\delta(u) = 0.035 + 0.02u^{1.05}$.

also the capital stock increases—which lowers the numerator in (39). In the long run, the latter effect is stronger, leading to a fall in capital utilization below its initial values.

Figure 7(d)–(f) shows the equilibrium response of output, consumption, and investment. Variable capital utilization implies that not only output, but also consumption rise on impact. Households anticipate higher future consumption to the increase in the capital stock. The desire to smooth consumption over time implies a willingness to consume more today. Variable capital utilizations allow households to do exactly that and effectively borrow from the future by sacrificing part of the capital stock. By using the capital stock at a higher rate today, households can experience an increase in their level of consumption on impact, at a cost of somewhat lower consumption in the future—because the capital stock depreciates faster as utilization increases.

5.3. Allowing for News about Future Trust

In the model we have described thus far, variations in trust are quite extreme: the economy can transition from significant collaboration ($Z_t = H$) to a complete breakdown of all types of collaboration ($Z_t = 0$). This choice is out of expositional simplicity. Here, we illustrate how we can extend the baseline model to allow for intermediate levels of collaboration—based on fluctuations in the likelihood that trust breaks down completely in the future—the probability that the state $Z_t = 0$ is reached.

In particular, we now allow the random variable Z_t to take values in $\{0, L, H\}$. As before, Z_t is persistent and evolves according to a continuous-time Markov chain with an instantaneous transition rate matrix given by

$$T = \begin{pmatrix} -\mu_{L,0} & \mu_{L,0} & 0 \\ \mu_{0,L} & -\mu_{0,L} - \mu_{H,L} & \mu_{H,L} \\ 0 & \mu_{L,H} & -\mu_{L,H} \end{pmatrix}. \tag{41}$$

The transition matrix (41) implies that only gradual changes are possible. Conditional on $Z_t = L$, the economy can transition to either the no-trust state ($Z_t = 0$) with instantaneous probability $\mu_{L,0}\,dt$ or to the high-trust regime with probability $\mu_{L,H}\,dt$. However, conditional on $Z_t = 0$, the economy can only transition to $Z_t = L$ over the next interval with probability $\mu_{0,L}\,dt$; similarly, conditional on $Z_t = H$, the economy can only transition to $Z_t = L$ with probability $\mu_{H,L}\,dt$. Importantly, Z_t cannot instantaneously switch between $Z_t = 0$ and $Z_t = H$.

Our formulation implies that a shift from $Z_t = H$ to $Z_t = L$ implies that the likelihood that trust breaks down in the future has increased. In particular, we use this randomization device to construct a correlated equilibrium. In this case, we construct an equilibrium such that

$$\begin{aligned} P_t(\theta) &= 1, && \left(\theta \le \theta_t^H \quad \text{and} \quad Z_t = H\right) \text{ or} \\ & && \left(\theta \le \theta_t^L \quad \text{and} \quad Z_t = L\right) \\ P_t(\theta) &= 0, && \text{otherwise.} \end{aligned} \tag{42}$$

That is, there is no collaboration when $Z_t = 0$. However, depending on the firms' value of reputation, some collaboration is feasible when $Z_t = L$ and $Z_t = H$. The relationship value to the firm can be written as

$$\begin{aligned} V_t^H &= \lambda\, E_t \int_t^{\tau_L} \frac{\Lambda_s}{\Lambda_t} \left(\int_0^{\theta_s^H} \pi_s^F(\theta)\, dF(\theta) \right) ds + E_t\left[\frac{\Lambda_{\tau_L}}{\Lambda_t} V_\tau^L \right] \\ V_t^L &= \lambda\, E_t \int_t^{\tau_H \wedge \tau_0} \frac{\Lambda_s}{\Lambda_t} \left(\int_0^{\theta_s^L} \pi_s^F(\theta)\, dF(\theta) \right) ds \\ &\quad + E_t\left[\frac{\Lambda_{\tau_H}}{\Lambda_t} V_\tau^H \right] + E_t\left[\frac{\Lambda_{\tau_0}}{\Lambda_t} V_\tau^0 \right] \\ V_t^0 &= E_t\left[\frac{\Lambda_{\tau_L}}{\Lambda_t} V_{\tau_L}^L \right], \end{aligned} \tag{43}$$

where τ_S is the random stopping time that Z_t switches to state S. In the two states where cooperation is feasible, the firm's IC constraint—Equation (12)—determines the set of projects that can be implemented in a partnerships. The two respective thresholds θ_t^L and θ_t^H are the largest solutions to

$$\begin{aligned} \pi_0\, \theta_t^H\, q_t^{H\frac{\hat{1}}{1-\alpha}} \left[(\underline{a})^{\frac{1}{1-\alpha}} + \eta\left(1 - (\underline{a})^{\frac{1}{1-\alpha}}\right) \right] &= V_t^H, \\ \pi_0\, \theta_t^L\, q_t^{L\frac{1}{1-\alpha}} \left[(\underline{a})^{\frac{1}{1-\alpha}} + \eta\left(1 - (\underline{a})^{\frac{1}{1-\alpha}}\right) \right] &= V_t^L. \end{aligned} \tag{44}$$

In this extension, the main driving force is essentially news about future levels of collaboration. That is, when $Z_t = 0$, trust breaks down, and like before, no collaboration occurs. Because the likelihood of reaching $Z_t = 0$ is different when $Z_t = L$ versus $Z_t = H$, the model also generates variation in the degree of collaboration between these two states L and H. In particular, when $Z_t = L$, there is some collaboration occurring. However, because now there is also a chance that trust disappears in the future—the state switches to $Z_t = 0$ at some point. Because the value of firms' reputation is forward looking, the value of firms' reputation is lower in that state, $V_t^L < V_t^H$. Because the cost of expropriation in that state is lower, there is also less collaboration, implying that $\theta_t^L \le \theta_t^H$.

In sum, the model can now generate shifts in the level of collaboration today—and hence the efficiency of investment—as a result of changes in beliefs about the future likelihood of collaboration. The mechanism is the same as in the baseline model—shocks to V_t directly affect the efficiency at which ideas are implemented into capital. Figure 8 illustrates this intuition graphically. We plot the impulse response of a (permanent) increase from $Z_t = L$ to $Z_t = H$. Comparing the figure to the results from the baseline model (Figure 5), we see that the response is qualitatively similar. That is, an increase from $Z_t = L$ to $Z_t = H$ increases the value of firms' reputation (Figure 8(c)), which implies that more projects can now be implemented into a partnership (Figure 8(a)). Because partnership is more efficient, the marginal efficiency of investment rises (Figure 8(b)). As before, this increase leads to a higher investment-to-output ratio, higher output, and higher productivity growth (Figure 8(d)–(f), respectively).

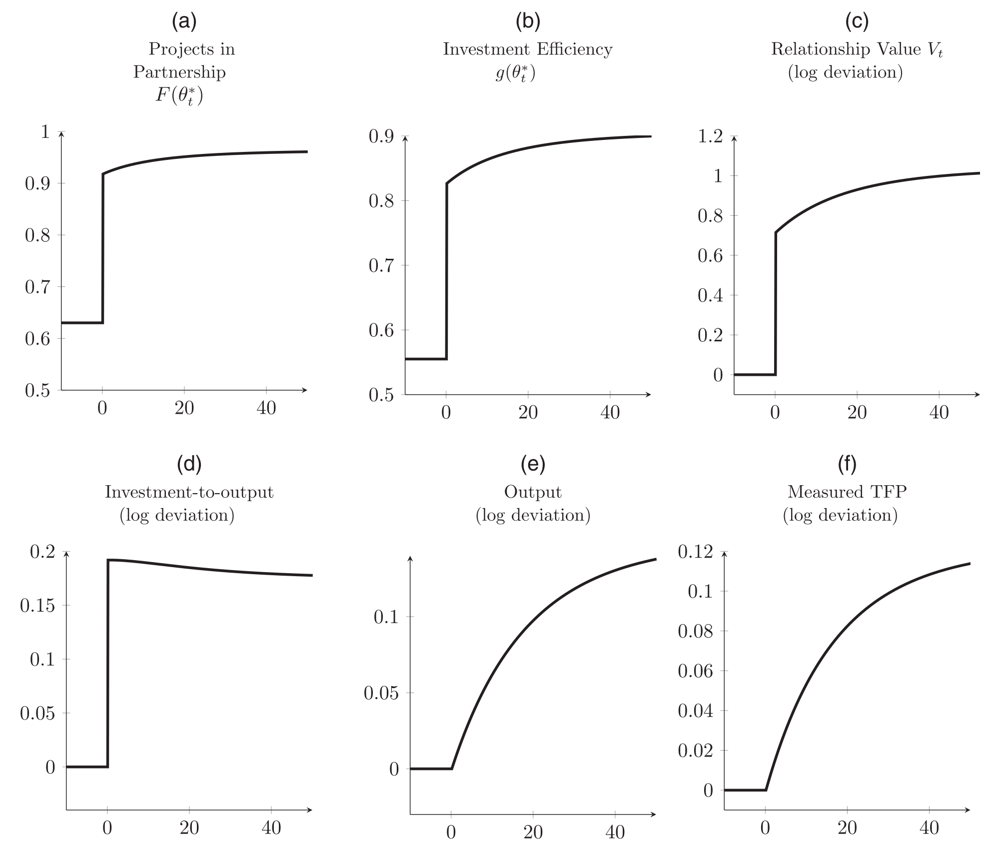
More broadly, this extension illustrates how shocks to the firms' reputation value V_t lead endogenously to an increase in the marginal efficiency of investment. That is, the only difference as the economy transitions between the two states $Z_t = L$ and $Z_t = H$ is shifts in the likelihood that collaboration breaks down at some point in the future (that is, we reach $Z_t = 0$). Shifts in the probability that a breakdown in trust occurs affect the value of firms' reputation and hence their incentive to not expropriate innovators. In general, any shock that directly affects V_t will lead to qualitatively the same predictions—for instance, shocks to the bargaining power of innovators; news about the quality of future projects; or changes in the firms' discount factors (that is, their survival probabilities).

5.4. Allowing for Firm Heterogeneity

The model we described thus far does not allow for any cross-sectional variation in the degree of trust within the same economy. To better connect the model with the firm-level evidence we document in Section 2, we next show how we can extend the model to allow for cross-sectional variation across firms in the degree of their trustworthiness. To simplify exposition, we shut down all sources of aggregate uncertainty.

We introduce firm heterogeneity by allowing the inventor's beliefs about whether firms can be trusted to vary in the cross section. Specifically, we allow the signal Z to be firm specific. That is, each firm is associated with its own public signal, $Z_{f,t}$, which evolves

Figure 8. Response to an Increase in Trust—Model with News About Future Trust



Notes. Figure plots log deviations from the steady state corresponding to $Z_t = L$ always in response to a permanent increase $Z_t = H$. The figure uses $\rho = 0.01$; $\gamma = 3$; $\beta = 1/3$; $\delta = 0.06$; $\lambda = 1$; $\alpha = 0.25$; $\underline{a} = 0.65$; $f(x) = e^{-x}$; $\eta = 1/2$; $\mu_{L,0} = 0.20$; $\mu_{0,L} = 0.01$; $\mu_{H,L} = 0.2$; and $\mu_{L,H} = 0.1$.

according to the transition matrix in (41). Shifts in $Z_{f,t}$ are uncorrelated across firms. As a result, at any given point in time, a constant fraction of firms

$$m_H = \frac{\mu_H}{\mu_0 + \mu_H}$$

are in the high-trust state, whereas the remaining are in the low-trust state.

As before, we assume that inventors are matched randomly to firms. After the match occurs, inventors observe the firm's current state $Z_{f,t}$—that is, they decide whether the firm is trustworthy or not. After observing $Z_{f,t}$, and given they know the quality of their project, they choose to collaborate with the firm or not. If $Z_{f,t} = 0$, innovators (correctly) anticipate being expropriated and therefore decide to implement the project on their own. If $Z_{f,t} = H$, then inventors are willing to collaborate—up to a point, that is, as long as $\theta \le \theta_t^*$. Recall that the total measure of new ideas each period is $\lambda\, dt$. Because matching is random, a fraction $1 - m_H$ of these ideas will be directed to low-trust firms, and hence they will never enter into a partnership. By contrast, a fraction m_H will be (potentially) implemented into high-trust firms.

At the aggregate level, the model with heterogenous firms behaves similarly as the baseline model without any uncertainty—subject to a few differences. First, the function $g(x)$ capturing the endogenous return to investment is now given by

$$g(x) \equiv m_H\, \bar\theta + (1 - m_H)\, \bar\theta\, (\underline{a})^{\frac{1}{1-\alpha}} - m_H \left(1 - \underline{a}^{\frac{1}{1-\alpha}}\right) \int_x^\infty \theta\, dF(\theta). \tag{45}$$

Comparing Equation (45) to the one in the baseline model with homogenous firms (28), we see that now there is an additional term reflecting the fact that some projects are always inefficiently implemented—because their inventors are matched with low-trust firms.

Second, the value of firms' reputation now depends on their current state

$$V_t^H = \lambda \int_t^\tau \frac{\Lambda_s}{\Lambda_t} \left(\int_0^{\theta_s^*} \pi_s^F(\theta)\, dF(\theta) \right) ds + E_t\left[\frac{\Lambda_\tau}{\Lambda_t} V_\tau^0 \right]$$
$$V_t^0 = E_t\left[\frac{\Lambda_\tau}{\Lambda_t} V_\tau^H \right]. \tag{46}$$

Last, the implementation threshold θ_t^* depends on the reputation value of the high-trust firms

$$\theta_t^*\, (q_t)^{\frac{1}{1-\alpha}} \left[(\underline{a})^{\frac{1}{1-\alpha}} + \eta \left(1 - (\underline{a})^{\frac{1}{1-\alpha}} \right) \right] = V_t^H.$$

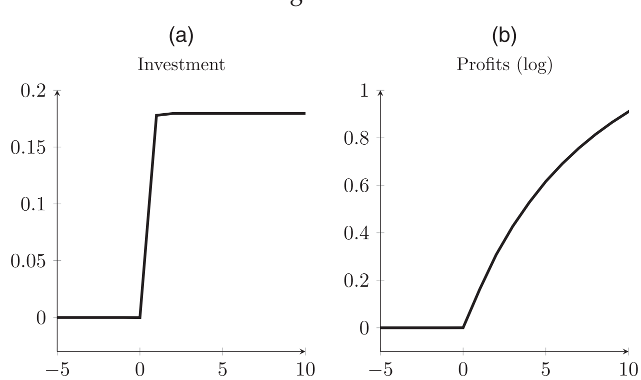
Figure 9 shows that the expanded model can generate variation in growth and investment across firms as a result of cross-sectional variation in $Z_{f,t}$. Innovators are more likely to collaborate with high- rather than low-trust firms, and hence these firms participate in the gains from implementing innovators' ideas. As a result, the model can qualitatively reproduce our findings in the second part of Section 2, where we document a robust empirical relation between firm-level measures of trust and innovation outcomes at the firm level.

6. Conclusion

We developed a macro model in which differences in the level of trust mitigate a hold-up friction in the creation of new capital. The key friction in the model is that the market for ideas is incomplete, so firms can expropriate inventors. The fear of expropriation leads innovators to implement their best ideas inefficiently without firms. The value of firms' reputation—the present value of future partnerships—limits expropriation, up to a point. An increase in the level of trust leads to greater collaboration between inventors and firms—and therefore to an increase in the marginal efficiency of investment. The model can qualitatively replicate the empirical relation between measures of trust and investment, innovation, and productivity growth—both at the macro and micro level.

The main driving force in the model is variation in the level of trust—which we model as a public signal that inventors and firms can use to coordinate their strategies. An advantage of our choice is that it allows us to map the model to the data and connect to the voluminous empirical literature documenting the effect of trust on economic growth. However, that is not the only possibility; any shock that directly affects the value of firms' reputation will also increase collaboration today. Examples include a shock to the profitability

Figure 9. Response to an Increase in Firm-Level Trust—Model with Heterogenous Firms



Notes. Figure plots deviations from the firms' steady state—a mixture of $Z_{f,t} = 0$ and $Z_{f,t} = H$—in response to a permanent increase $Z_{f,t} = H$. The figure uses $\rho = 0.01$; $\gamma = 3$; $\beta = 1/3$; $\delta = 0.06$; $\lambda = 0.85$; $\alpha = 0.4$; $\underline{a} = 0.65$; $f(x) = e^{-x}$; $\mu_L = 0.2$; and $\mu_H = 0.1$. The model features no aggregate uncertainty, so all simulations are at the aggregate (deterministic) steady state.

of future projects; an increase in the share of rents captured by firms; and a shift in the likelihood that a given firm survives in the future, which will affect how much it cares about its reputation when considering whether to expropriate inventors. Given that our model is quite tractable, allowing for any of these additional forces is relatively straightforward and can potentially lead to several additional empirical implications.

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A. Analytical Appendix
A.1. Analytical Derivations
To conserve space, in Section 6, we provide the solution to a model that nests the baseline model and the two extensions considered in Section 5 that allow for endogenous labor supply and varying capital utilization. In Section 6, we provide the solution to the model with heterogenous firms—but no aggregate uncertainty.

A.1.1. Model with Homogenous Firms. We begin by examining the optimal investment policy in a project of quality θ given the partnership decision $P_t(\theta)$. We guess, and subsequently verify, that the optimal partnership policy takes the form $P_t(\theta) = 1$ iff $\theta < \theta_t^*$. At the time of investment, the owner of a project chooses scale x to maximize

$$\pi_t = \max_x \{q_t\, a(\theta)\, \theta^{1-\alpha} x^\alpha - x\} \tag{A.1}$$

yielding
$$x_t^*(\theta) = \theta \left(\alpha q_t\, a(\theta)\right)^{\frac{1}{1-\alpha}} \tag{A.2}$$

and

$$\pi_t = \theta\, \pi_0 \left(a(\theta) q_t\right)^{\frac{1}{1-\alpha}}, \qquad \pi_0 \equiv (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}}.$$

The total demand for new capital clears the market for investment goods

$$\begin{aligned} I_t &= \lambda \int_0^\infty x_t^*(\theta) dF(\theta) \\ &= \lambda \int_0^\infty \theta \left(\alpha q_t\, a(\theta)\right)^{\frac{1}{1-\alpha}} dF(\theta) \\ &= \lambda \left(\alpha q_t\right)^{\frac{1}{1-\alpha}} \underbrace{\left(\bar{\theta} - \left(1 - \underline{a}^{\frac{1}{1-\alpha}}\right) \int_{\theta_t^*}^\infty \theta\, dF(\theta)\right)}_{g(\theta_t^*)}. \end{aligned} \tag{A.3}$$

New capital created at time t is given by

$$\begin{aligned} \lambda \int_0^\infty a(\theta)\theta^{1-\alpha} x_t^*(\theta)^\alpha dF(\theta) &= \lambda \left(\alpha q_t\right)^{\frac{\alpha}{1-\alpha}} \int_0^\infty a(\theta)^{\frac{1}{1-\alpha}} \theta dF(\theta) \\ &= \lambda \left(\alpha q_t\right)^{\frac{\alpha}{1-\alpha}} g(\theta_t^*) \\ &= \left(\lambda\, g(\theta_t^*)\right)^{1-\alpha} I_t^\alpha. \end{aligned} \tag{A.4}$$

As a result, the capital accumulation equation becomes

$$dK_t = \left(I_t^\alpha \left(\lambda\, g(\theta_t^*)\right)^{1-\alpha} - \delta\right) K_t\, dt. \tag{A.5}$$

The next step is to solve for the state-dependent threshold θ_t^*. To do so, we need to derive the relationship value to the firm.

Table A.1. Firm-Level Trust, Patenting, and Inventor Mobility: Disaggregated Trust Measures

	(1) Patents	(2) 90 percentile patents	(3) 75 percentile patents
Trust sentiment	0.066***	0.059***	0.068***
	(0.018)	(0.018)	(0.017)
Trust incidence	−0.001	−0.013	−0.016
	(0.026)	(0.024)	(0.024)
Full controls	Yes	Yes	Yes
R^2	0.872	0.804	0.844
Observations	3,136	2,805	2,938

Notes. Regressions are at the firm-year level. Full controls include firm R&D expenditure, assets, and profits; the number of inventors a firm has; the number of Glassdoor reviews for a firm (fixed effects in deciles of these latter two variables); year fixed effects; and fixed effects for two-digit SIC. Patenting refers to the log of one plus the number of patents granted to that firm in a given year; stock market value refers to the sum of patent values as measured in Kogan et al. (2017); 90th and 75th percentile patenting refers to the log of 1 plus the number of patents in a given firm year that were in the top 90th or 75th percentile of forward citations for patents of the same patent class (CPC)–grant year cohort. Trust incidence and sentiment are measured as using text analysis of Glassdoor review data, as in Sull (2018), and standardized to have mean 0 and SD 1. We report t-statistics in parentheses; standard errors are computed as in White (1980).

***Significance at the 1% level.

First, consider the case in which there is always cooperation, that is $(Z_t = 1)$ always. If a project is implemented in a partnership, the firm obtains

$$\pi_t^F(\theta) = \big(1-\eta\big)\big(\pi_t^* - \underline{\pi}_t\big) = \theta\,(1-\eta)\,\pi_0\,(q_t)^{\frac{1}{1-\alpha}}\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big), \tag{A.6}$$

where

$$\pi_0 \equiv (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}}.$$

Integrating over projects with quality $\theta \le \theta_t^*$, we get

$$\int_0^{\theta_t^*} \pi_t^F(\theta)\,dF(\theta) = \big(1-\eta\big)\,\pi_0\,(q_t)^{\frac{1}{1-\alpha}}\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big)\int_0^{\theta_t^*}\theta\,dF(\theta).$$

The relationship value to the firm is then given by

$$V_t = \lambda\,E_t\int_t^\infty \frac{\Lambda_s}{\Lambda_t}\left(\int_0^{\theta_t^*}\pi_t^F(\theta)\,dF(\theta)\right)ds = \lambda\,(1-\eta)\,\pi_0\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big)\,E_t\int_t^\infty\frac{\Lambda_s}{\Lambda_t} \times\left((q_s)^{\frac{1}{1-\alpha}}\int_0^{\theta_s^*}\theta\,dF(\theta)\right)ds. \tag{A.7}$$

In a partnership, the innovator obtains a payoff equal to

$$\pi_t^I(\theta) = \underline{\pi}_t + \eta\,(\pi_t^* - \underline{\pi}_t) = \theta\,\pi_0\,(q_t)^{\frac{1}{1-\alpha}}\Big[(\underline{a})^{\frac{1}{1-\alpha}} + \eta\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big)\Big]. \tag{A.8}$$

Hence, the firm can credibly commit not to expropriate the inventor as long as

$$\pi_t^I(\theta) \le V_t$$
$$\theta\,\pi_0\,(q_t)^{\frac{1}{1-\alpha}}\Big[(\underline{a})^{\frac{1}{1-\alpha}} + \eta\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big)\Big] \le v_0\,E_t\int_t^\infty\frac{\Lambda_s}{\Lambda_t}\left((q_s)^{\frac{1}{1-\alpha}}\int_0^{\theta_s^*}\theta\,dF(\theta)\right)ds, \tag{A.9}$$

where

$$v_0 \equiv \lambda\,(1-\eta)\,\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big)\,\pi_0, \tag{A.10}$$

that is, θ is below a state-dependent threshold θ_t^*.

Now, consider the case in which Z varies over time as in the baseline case. In this case, the expression for V_t needs to be modified to

$$V_t^H = \lambda\int_t^\tau\frac{\Lambda_s}{\Lambda_t}\left(\int_0^{\theta_s^H}\pi_s^F(\theta)\,dF(\theta)\right)ds + E_t\left[\frac{\Lambda_\tau}{\Lambda_t}\,V_\tau^0\right]$$
$$V_t^0 = E_t\left[\frac{\Lambda_\tau}{\Lambda_t}\,V_\tau^H\right], \tag{A.11}$$

and the quality of the marginal project to be implemented in a partnership is the solution to

$$\theta\,(q_t)^{\frac{1}{1-\alpha}}\Big[(\underline{a})^{\frac{1}{1-\alpha}} + \eta\Big(1-(\underline{a})^{\frac{1}{1-\alpha}}\Big)\Big] \le V_t^H.$$

Next, we solve for the price of capital. The market value of an existing project j is

$$a\big(\theta_j\big)\,\theta_j^{1-\alpha}k_j^\alpha\,\underbrace{\max_u E_t\int_t^\infty e^{\int_t^s -\delta(u_\tau)d\tau}\frac{\Lambda_s}{\Lambda_t}\,p_s^K\,u_s\,ds}_{q_t}, \tag{A.12}$$

where here, p_t^K is the price of capital services paid by the final-goods firm, and u is the choice of capital utilization. We can immediately see that all projects will have the same rate of capital utilization regardless of quality.

We next solve for the evolution of the aggregate state. Because u_t is only depending on aggregate variables, we have that the effective supply of capital services equals

$$\hat{K}_t = \bar{u}_t\,K_t, \tag{A.13}$$

where $\bar{u}_t$ is the equilibrium rate of capital utilization. The household's labor supply decision is intra-temporal, implying

$$L_t = 1-\psi\,\frac{C_t}{w_t} = \left(1+\frac{\psi}{1-\beta}\,(1-i_t)\right)^{-1}, \tag{A.14}$$

where $i_t \equiv I_t/Y_t$ is the investment-to-output ratio, and we used the standard condition that the equilibrium share of labor is $w_tL_t = (1-\beta)Y_t$.

Aggregate output is

$$Y_t = (u_t\,K_t)^\beta\,L_t^{1-\beta}. \tag{A.15}$$

Plugging the above into (17)

$$\frac{dK_t}{K_t} = \underbrace{\left[\left(i_t\,u_t^\beta\,L_t^{1-\beta}\right)^\alpha\big(\lambda\,g(\theta_t^*)\big)^{1-\alpha}\,K_t^{\alpha\beta-1} - \delta(u_t)\right]}_{\kappa(\omega_t,Z_t)}dt. \tag{A.16}$$

The capital stock K is a state variable along with the current level of trust Z_t. We write

$$\omega_t \equiv \big(\alpha\beta-1\big)\log K_t \tag{A.17}$$

and

$$\kappa(\omega_t,Z_t) \equiv e^{\omega_t}\left(i_t\left(u_t^\beta\,L_t^{1-\beta}\right)\right)^\alpha\big(\lambda\,g(\theta_t^*)\big)^{1-\alpha} - \delta(\bar{u}), \tag{A.18}$$

given our conjecture, which we verify below, that hours L_t, utilization $\bar{u}_t$, investment-to-output ratio i_t, and threshold χ_t are functions of ω and Z. In what follows, we make this dependence explicit. Because Z is a two-point process, to economize on notation we will write $f(\omega, Z=x)$ as $f^x(\omega)$.

The next step involves computing q_t and V_t explicitly. Standard optimality results imply that the state price density Λ satisfies

$$\Lambda_t = e^{-\rho t}C_s^{-\gamma}\big(N_s^\psi\big)^{1-\gamma} = e^{-\rho t}K_t^{-\gamma\beta}\underbrace{\begin{array}{c}\left(u_t^\beta\left(1+\frac{\psi}{1-\beta}\,(1-i_t)\right)^{\beta-1}\right)^{-\gamma}(1-i_t)^{-\gamma} \\ \times\left(1-\left(1+\frac{\psi}{1-\beta}\,(1-i_t)\right)^{-1}\right)^{\psi(1-\gamma)}\end{array}}_{A(\omega_t,Z_t)}. \tag{A.19}$$

Using the equation for the state price density (A.19), along with the fact that, in equilibrium, the price of capital services paid by the final goods firm is equal to

$$p_t^K \hat{K}_t = \beta Y_t,$$

we get that

$$\begin{aligned} K_t^{-\gamma\beta} A(\omega_t, Z_t) q_t &= \max_u E_t \int_t^\infty e^{-\int_t^s (\rho+\delta(u_\tau))d\tau} K_s^{-\gamma\beta} \\ &\quad \times A(\omega_s, Z_s)\, \beta\, u_s \frac{Y_s}{\bar{u}_s} K_s^{-1}\, ds. \\ K_t^{-\gamma\beta} A(\omega_t, Z_t) q_t &= \max_u E_t \int_t^\infty e^{-\int_t^s (\rho+\delta(u_\tau))d\tau} K_s^{\beta(1-\gamma)-1} \\ &\quad \times A(\omega_s, Z_s)\, \beta\, u_s \left(\frac{L_s}{u_s}\right)^{1-\beta} ds. \\ A(\omega_t, Z_t) q_t &= K_t^{\beta-1} \max_u E_t \int_t^\infty e^{-\int_t^s (\rho+\delta(u_\tau))d\tau} \left(\frac{K_s}{K_t}\right)^{\beta(1-\gamma)-1} \\ &\quad \times A(\omega_s, Z_s)\, \beta\, u_s \left(\frac{L_s}{u_s}\right)^{1-\beta} ds. \end{aligned}$$

Here, a reasonable guess is that

$$q_t = K_t^{\beta-1} m(\omega_t, Z_t)(A(\omega_t, Z_t))^{-1}. \tag{A.20}$$

To go from present values to a differential equation, we use the Feynman-Kac theorem with discounting. Because Z is a two-point process, we write $m(\omega_t, Z_t = L) = m^L(\omega_t)$ and $m(\omega_t, Z_t = H) = m^H(\omega_t)$. That is, these two functions solve the nested Ordinary Differential Equations (ODEs)

$$\begin{aligned} 0 = \max_u &\Big\{\beta A^L(\omega)\left(\frac{L}{\bar{u}}\right)^{1-\beta} u - (1-\alpha\beta)\kappa^L(\omega)\frac{\partial}{\partial\omega} m^L(\omega) \\ &- m^L(\omega)\big[\rho - (\beta(1-\gamma)-1)\kappa^L(\omega) + \delta(u)\big] + \mu_H\big(m^H(\omega) - m^L(\omega)\big)\Big\} \\ 0 = \max_u &\Big\{\beta A^H(\omega)\left(\frac{L}{\bar{u}}\right)^{1-\beta} u - (1-\alpha\beta)\kappa^H(\omega)\frac{\partial}{\partial\omega} m^H(\omega) \\ &- m^H(\omega)\big[\rho - (\beta(1-\gamma)-1)\kappa^H(\omega) + \delta(u)\big] - \mu_L\big(m^H(\omega) - m^L(\omega)\big)\Big\}. \end{aligned}$$

Importantly, when optimizing over capital utilization, the firm takes the aggregate utilization $\bar{u}$ s given. The first-order conditions for capital utilization (Equation (39)) therefore becomes

$$\beta A(\omega, Z)\left(\frac{L}{\bar{u}}\right)^{1-\beta} = m(\omega, Z)\, \delta'(u^*). \tag{A.21}$$

Equation (A.21), along with the symmetry condition $\bar{u} = u$, pins down the equilibrium level of u.

The value of a project of quality θ at time t thus can be derived as

$$\begin{aligned} \pi_t &= \theta\, \pi_0\, (a(\theta) q_t)^{\frac{1}{1-\alpha}} \\ &= \theta\, \pi_0 \left(a(\theta) K_t^{\beta-1} m(\omega_t, Z_t)\big(A(\omega_t, Z_t)\big)^{-1}\right)^{\frac{1}{1-\alpha}} \\ &= \theta\, \pi_0\, K_t^{\beta}\left(a(\theta)\, e^{\omega_t} m(\omega_t, Z_t)\big(A(\omega_t, Z_t)\big)^{-1}\right)^{\frac{1}{1-\alpha}}. \end{aligned}$$

Last, we solve for the relationship values of the firm. Recall,

$$\begin{aligned} \Lambda_t V_t^H &= v_0 \int_t^\tau \Lambda_s\, (q_s)^{\frac{1}{1-\alpha}} \left(\int_0^{\theta_s^H} \theta\, dF(\theta)\right) ds + E_t[\Lambda_\tau V_\tau^0] \\ \Lambda_t V_t^0 &= E_t[\Lambda_\tau V_\tau^H]. \end{aligned} \tag{A.22}$$

After substituting for q_t and Λ_t, we have

$$\begin{aligned} A(\omega_t, Z_t) V_t^H = K_t^\beta v_0 &\int_t^\tau e^{-\rho(s-t)} \left(\frac{K_s}{K_t}\right)^{(1-\gamma)\beta} \\ &\times (A(\omega_s, Z_s))^{-\frac{\alpha}{1-\alpha}} (e^{\omega_s} m(\omega_s, Z_s))^{\frac{1}{1-\alpha}} \\ &\times \left(\int_0^{\theta_s^H} \theta\, dF(\theta)\right) ds + E_t[\Lambda_\tau V_\tau^0]. \end{aligned} \tag{A.23}$$

Using a similar reasoning as above, we conjecture that the relationship value takes the form

$$\begin{aligned} V_t^H &= K_t^\beta v^H(\omega_t)\big(A^H(\omega_t)\big)^{-1} \\ V_t^0 &= K_t^\beta v^0(\omega_t)\big(A^0(\omega_t)\big)^{-1}, \end{aligned} \tag{A.24}$$

where again using the discounted version of the Feynman-Kac theorem to go from present values to differential equations, we obtain a nested pair of ODEs

$$\begin{aligned} 0 = &\Big\{v_0\big(e^\omega m^H(\omega)\big)^{\frac{1}{1-\alpha}} \big(A^H(\omega)\big)^{-\frac{\alpha}{1-\alpha}} \\ &\times \int_0^{\theta_H(\omega)} \theta.dF(\theta) - (1-\alpha\beta)\,\kappa^H(\omega)\frac{\partial}{\partial\omega} v^H(\omega) \\ &- v^H(\omega)\big(\rho - \beta(1-\gamma)\,\kappa^H(\omega)\big) + \mu_0\big(v^0(\omega) - v^H(\omega)\big)\Big\} \\ 0 = &\Big\{-(1-\alpha\beta)\,\kappa^L(\omega)\frac{\partial}{\partial\omega} v^0(\omega) \\ &- v^0(\omega).\big(\rho - \beta(1-\gamma)\,\kappa^0(\omega)\big) - \mu_H\big(v^0(\omega) - v^H(\omega)\big)\Big\}. \end{aligned}$$

The remaining parts consist of verifying that the rest of the policy functions are indeed only functions of ω and Z. The equation for the partnership threshold

$$\theta_t^H \pi_0 \left(\frac{m^H(\omega_t)}{A^H(\omega_t)}\right)^{\frac{1}{1-\alpha}} \left[(\underline{a})^{\frac{1}{1-\alpha}} + \eta\left(1 - (\underline{a})^{\frac{1}{1-\alpha}}\right)\right] = \frac{v^H(\omega_t)}{A^H(\omega_t)} \tag{A.25}$$

illustrates that this is indeed the case. Given (A.21), the same is true for the rate of capital utilization. The last step is to verify that the same is true for the investment-to-output ratio. Rearranging Equation (A.3), we obtain

$$\begin{aligned} &\lambda\left(\alpha e^{\omega_t} m^H(\omega_t)\big(A^H(\omega_t)\big)^{-1}\right)^{\frac{1}{1-\alpha}} g(\theta^H(\omega_t)) \\ &\quad \times \left(u^H(\omega)^\beta L^H(\omega)^{1-\beta}\right)^{-1} = i^H(\omega) \\ &\lambda\left(\alpha e^{\omega_t} m^0(\omega_t)\big(A^0(\omega_t)\big)^{-1}\right)^{\frac{1}{1-\alpha}} g(0) \\ &\quad \times \left(u^0(\omega)^\beta L^0(\omega)^{1-\beta}\right)^{-1} = i^0(\omega). \end{aligned} \tag{A.26}$$

In the version of the model where Z_t can take three possible values, $Z_t = 0, L, H$, we follow the same steps, in which we obtain a similar set of nested ODEs. For example, the set of ODEs characterizing relationship values will be

$$0 = \Big\{ v_0\big(e^{\omega}\, m^H(\omega)\big)^{\frac{1}{1-\alpha}} \big(A^H(\omega)\big)^{-\frac{\alpha}{1-\alpha}} \int_0^{\theta^H(\omega)} \theta dF(\theta) - (1-\alpha\beta)\,\kappa^H(\omega)\, \frac{\partial}{\partial\omega} v^H(\omega) - v^H(\omega) \times \big(\rho - \beta(1-\gamma)\,\kappa^H(\omega)\big) + \mu_{H,L}\big(v^L(\omega) - v^H(\omega)\big) \Big\}$$

$$0 = \Big\{ v_0\big(e^{\omega}\, m^L(\omega)\big)^{\frac{1}{1-\alpha}} \big(A^L(\omega)\big)^{-\frac{\alpha}{1-\alpha}} \int_0^{\theta^L(\omega)} \theta dF(\theta) - (1-\alpha\beta)\,\kappa^L(\omega)\, \frac{\partial}{\partial\omega} v^L(\omega) - v^L(\omega)\big(\rho - \beta(1-\gamma)\,\kappa^L(\omega)\big) + \mu_{L,0}\big(v^0(\omega) - v^L(\omega)\big) + \mu_{L,H}\big(v^H(\omega) - v^L(\omega)\big) \Big\}$$

$$0 = \Big\{ -(1-\alpha\beta)\,\kappa^L(\omega)\, \frac{\partial}{\partial\omega} v^0(\omega) - v^0(\omega)\big(\rho - \beta(1-\gamma)\,\kappa^0(\omega)\big) - \mu_{0,L}\big(v^0(\omega) - v^L(\omega)\big) \Big\}.$$

A.1.2. Model with Heterogenous Firms.

In the model with heterogenous firms, we now assume that the trust variable $Z_{f,t}$ is now firm specific. For simplicity, we shut down aggregate uncertainty, so $Z_{f,t}$ is uncorrelated across firms. The evolution of $Z_{f,t}$ is still given by the matrix T in equation. As a result, at any point in time, a measure

$$m_H = \frac{\mu_H}{\mu_0 + \mu_H}$$

firms are in the high-trust state and a measure $1 - m_H$ are in the low-trust state.

As before, inventors are matched randomly to firms. After the match, inventors learn the firm's current state $Z_{f,t}$, at which point they choose to collaborate or not. Each period, a measure $\delta^h\, dt$ inventors are born. Each inventor has a measure of ideas equal to λ/δ^h so the total measure of new ideas each period is $\lambda\, dt$. Because matching is random, a fraction $1 - m_H$ of these ideas will be directed to low-trust firms, and hence they will never enter into a partnership. By contrast, a fraction m_H will be (potentially) implemented into high trust firms.

The optimal investment policy in a project of quality θ given the partnership decision $P_t(\theta)$ remains unchanged. At the time of investment, the owner of a project chooses scale x to maximize

$$\pi_t = \max_x \{q_t\, a(\theta)\, \theta^{1-\alpha} x^{\alpha} - x\}, \tag{A.27}$$

yielding
$$x_t^*(\theta) = \theta\, \big(\alpha q_t\, a(\theta)\big)^{\frac{1}{1-\alpha}}, \tag{A.28}$$

and

$$\pi_t = \theta\, \pi_0\, \big(a(\theta) q_t\big)^{\frac{1}{1-\alpha}}, \qquad \pi_0 \equiv (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}}.$$

What is different now is the market clearing condition for investment goods.

$$\begin{aligned} I_t &= \lambda \int_0^{\infty} x_t^*(\theta) dF(\theta) \\ &= \lambda \int_0^{\infty} \theta\, \big(\alpha q_t\, a(\theta)\big)^{\frac{1}{1-\alpha}} dF(\theta) \\ &= \lambda\, (\alpha q_t)^{\frac{1}{1-\alpha}} \underbrace{\left[m_H\, \bar\theta + (1-m_H)\, \bar\theta\, (\underline{a})^{\frac{1}{1-\alpha}} - m_H \left(1 - \underline{a}^{\frac{1}{1-\alpha}}\right) \int_{\theta_t^*}^{\infty} \theta\, dF(\theta) \right]}_{g(\theta_t^*)} \end{aligned} \tag{A.29}$$

New capital created at time t is given by

$$\begin{aligned} &\lambda\, m_H \int_0^{\infty} a(\theta)\theta^{1-\alpha}\, x_t^*(\theta)^{\alpha} dF(\theta) \\ &\quad + \lambda\,(1-m_H) \int_0^{\infty} \underline{a}\theta^{1-\alpha}\, x_t^*(\theta)^{\alpha} dF(\theta) \\ &= \lambda\, m_H\, (\alpha q_t)^{\frac{\alpha}{1-\alpha}} \int_0^{\infty} a(\theta)^{\frac{1}{1-\alpha}} \theta dF(\theta) \\ &\quad + \lambda\,(1-m_H)\,(\alpha q_t)^{\frac{\alpha}{1-\alpha}}\, \underline{a}^{\frac{1}{1-\alpha}} \bar\theta \\ &= \lambda\, (\alpha q_t)^{\frac{\alpha}{1-\alpha}}\, g(\theta_t^*) \\ &= \big(\lambda\, g(\theta_t^*)\big)^{1-\alpha} I_t^{\alpha}. \end{aligned} \tag{A.30}$$

As a result, the capital can still be written as follows:

$$dK_t = \Big(I_t^{\alpha}\, \big(\lambda\, g(\theta_t^*)\big)^{1-\alpha} - \delta \Big)\, K_t\, dt. \tag{A.31}$$

The next step is to solve for the state-dependent threshold θ_t^*. To do so, we need to derive the relationship value to each type of firm (H,L)

$$\begin{aligned} V_t^H &= \lambda \int_t^{\tau} \frac{\Lambda_s}{\Lambda_t} \left(\int_0^{\theta_s^*} \pi_s^F(\theta)\, dF(\theta) \right) ds + E_t\left[\frac{\Lambda_\tau}{\Lambda_t}\, V_\tau^0 \right] \\ V_t^0 &= E_t\left[\frac{\Lambda_\tau}{\Lambda_t}\, V_\tau^H \right], \end{aligned} \tag{A.32}$$

and for high-trust firms, the quality of the marginal project to be implemented in a partnership is the solution to

$$\theta_t^*\, (q_t)^{\frac{1}{1-\alpha}} \Big[(\underline{a})^{\frac{1}{1-\alpha}} + \eta \Big(1 - (\underline{a})^{\frac{1}{1-\alpha}}\Big) \Big] = V_t^H.$$

In brief, the model is similar to the baseline model up to a re-definition of $g(\theta_t^*)$ and the fact that there is no aggregate uncertainty—that is, the threshold θ_t^* now only depends on ω_t.

A.2. Numerical Solution

The solution of the model is characterized by a system of partial differential equations (PDEs) $m(\omega, Z)$ and $v(\omega, Z)$; the first-order conditions (A.14), (A.21), and (A.26); and the condition determining the threshold (A.25). To solve the model, we take the following steps:

(1) We first approximate the unknown functions $v(\omega, Z)$ and $m(\omega, Z)$ on an equally spaced grid for ω of size N. We choose a spacing of $h = 1/300$, and the end points as $\omega_1 = -4$ and $\omega_N = 1$.

Table A.2. Firm-Level Trust, Patenting, and Inventor Mobility: Disaggregated Trust Measures

	(1) Inventor patents	(2) Inventor cites	(3) Inventor exit (log(1 + #))	(4) Inventor entry (log(1 + #))	Inventor exit (quality pctile)	
					(5) Patenting	(6) Cites
Trust sentiment	0.005	−0.027	−0.021**	0.113***	−0.315***	−0.124
	(0.009)	(0.019)	(0.009)	(0.009)	(0.054)	(0.088)
Trust incidence	0.016	0.068***	0.015	0.016	−0.161*	−0.451***
	(0.015)	(0.025)	(0.013)	(0.013)	(0.092)	(0.133)
Full controls	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.661	0.617	0.967	0.969	0.631	0.571
Observations	2,119	2,110	3,136	3,136	1,408	1,408

Notes. Regressions are at the firm-year level. Full controls include firm R&D expenditure, assets, and profits; the number of inventors a firm has; the number of Glassdoor reviews for a firm (fixed effects in deciles of these latter two variables); and year fixed effects. Patenting refers to the log of one plus the number of patents granted to that firm in a given year; 90th and 75th percentile patenting refers to the log of one plus the number of patents in a given firm year that were in the top 90th or 75th percentile of forward citations for patents of the same patent class (CPC)–grant year cohort; inventor exit refers to the log of 1 plus the number of inventors that exit (controlling for total inventors); inventor entry is defined analogously for inventors who enter, as in Jung (2019). Inventor exit quality pctile refers to the within firm-year percentile in patenting output of exiting inventors, measured either by total patents or total citations to all patents. Trust incidence and sentiment are measured as using text analysis of Glassdoor review data, as in Sull (2018), and standardized to have mean 0 and SD 1. We report t-statistics in parentheses; standard errors are computed as in White (1980).

***,**, and *Significance at the 1%, 5%, and 10% levels, respectively.

(2) We next approximate the first derivatives using finite differences. For instance, $v'(\omega)$ at the point ω_n can be approximated as

$$v'(\omega_n) = \frac{v_{n+1} - v_{n-1}}{2h}.$$

Replacing the approximation into Equations (6) and (6) yields, for each equation, a system of $N-2$ equations in N unknowns. The boundary conditions $v'(\omega_1) = 0$ and $v'(\omega_N) = 0$ provide two additional equations for a total of N equations using N unknowns.

(3) We then implement the following iterative scheme. We first start with a guess for the policy functions $i(\omega, Z)$, $u(\omega, Z)$, and $\theta^H(\omega, Z)$.

(a) Given policy functions $i(\omega, Z)$, $u(\omega, Z)$, and $\theta^H(\omega)$, solve for $v(\omega, Z)$ and $m(\omega, Z)$ using the finite-difference approximation above.

(b) Given then new functions $v(\omega, Z)$ and $m(\omega, Z)$, solve for the optimal policies using (A.14), (A.21), (A.25), and (A.26).

(c) Repeat steps (a) and (b) until convergence.

Endnotes

[1] Arrow (1962, pp. 615–616) writes: “There is a fundamental paradox in the determination of demand for information; its value for the purchaser is not known until he has the information, but then he has acquired it without cost.”

[2] This assumption greatly simplifies our analysis. A potential concern however is that, if innovators share risks, why do they worry about being expropriated? We could modify the assumption of large families by assuming that new innovators start with wealth that is proportional to the value of their own idea, scaled by the average value of all ideas at time t. This alternative setup yields qualitatively similar predictions.

[3] For instance, E. H. Armstrong pioneered FM radio in the 1910s and 1920s. However, all of Armstrong’s inventions were claimed by others. The regenerative circuit, which Armstrong patented in 1914 as a wireless receiving system, was subsequently patented by Lee De Forest in 1916; De Forest then sold the rights to his patent to AT&T. Furthermore, once disclosed, the ideas can be implemented without the innovator, who is often not crucial to the success of the venture. For example, Robert Kearns patented the intermittent windshield wiper in 1967. He tried to interest the Big Three auto makers in licensing the technology. They all rejected his proposal, yet began to install intermittent wipers in their cars, beginning in 1969. Kearns ultimately won the patent lawsuit against Ford in 1978 and Chrysler in 1982.

[4] This is often possible because of contractual features of the VC arrangement (see, e.g., Kaplan and Stromberg 2004). For instance, as described in Atanasov, Ivanov, and Litvak (2012), the founder of Pogo.com, an e-gaming company, sued the VCs on the board for issuing complicated derivative securities, effectively reducing his stake from 13% to 0.1% and then refusing to redeem his stock in violation of prior agreement. Similarly, VCs are at times better informed than the innovators and this permits other opportunities to expropriate. For example, the founders of Epinions, a consumer product review website, sued three VC funds for fraudulently withholding information that caused them multimillion-dollar losses. The founders alleged that the financiers persuaded them to give up their ownership interests after being led to believe that the value of their stake was zero. At the time, the VCs had indicated that the value the company was approximately $30 million, well below its $45 million liquidation preference. The founders alleged that, a year later, the implied value of the company was $300 million, partly due to a deal with Google and other financial results and projections that were not disclosed by the VCs.

[5] For example, in the late 1980s, software maker Peoplesoft and its founder David Duffield were sued by Integral Systems, which claimed that its software was based on computer code that was stolen from the company while Mr. Duffield worked there.

[6] A recent example is Venezuela’s expropriation of oil projects in the Orinoco Belt in 2007. Historically, the lack of appropriate mechanisms open to foreign investors to protect projects and the associated risks caused a restriction in the flow of international investment into certain countries. To overcome this difficulty, there have been an increasing number of contractual protections that offer some measure of protection. However, the efficiency of these measures is limited for several reasons. First, expropriation can take many indirect forms, such as changes to taxation, environmental protection, or labor laws. Second, new governments can choose to default on contracts signed by their predecessors.

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