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Financial Crises, Firms' Innovation and the Macroeconomy

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Abstract

This dissertation analyzes the interaction between financial crises and firms' innovation, its macroeconomic consequences and the implications for economic policy. The first chapter, "The Financing of Ideas and the Great Deviation", studies the macroeconomic impact of financial shocks through their negative effect on intangible capital investment, using a panel dataset of Spanish manufacturing firms. The second chapter, "How Destructive is Innovation?", is co-authored with Chang-Tai Hsieh and Peter J. Klenow. It quantifies the contribution of different innovation channels to aggregate economic growth, matching a growth model to statistical moments on establishment dynamics in the U.S. The final chapter, "Macroprudential Policy with Liquidity Panics", is co-authored with Alonso Villacorta. It shows how financial panics can appear endogenously due to precautionary cash accumulation by firms, and how this changes the optimal macroprudential policy.

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Chapter 1: The Financing of Ideas and the Great Deviation

The 2007-2008 Global Financial Crisis has been followed by a large contraction in GDP and a particularly slow recovery in many developed economies, especially in the European periphery. The Great Recession has turned into a "Great Deviation" of output from trend. This paper presents a model that explains why the response of the real economy can be larger and more persistent after a financial shock than after other types of shocks. The mechanism is based on the interaction between investment in intangible capital and financial constraints. Financial shocks make financing intangibles disproportionately more costly, and the consequent fall in intangible capital accumulation generates a prolonged deviation in output. I estimate the model with panel data on Spanish manufacturing firms and find that modeling intangible investment accounts for more than half of the fall in value added between 2008 and 2013. The paper also delivers quantitative recommendations for fiscal policy based on firm characteristics.

I model the corporate sector in a small open economy. Heterogeneous firms invest in physical (or tangible) capital and in intangible capital. Intangible investment includes all expenditures in non-physical assets aimed at increasing the productivity of a firm. Thus, it captures the formation of both technological and organizational capital. Firms finance their investments with internal equity and debt—the most common channels in Europe. Yet, they have limited commitment and can default on their debt obligations. The corporate sector is subject to financial and non-financial aggregate shocks. Both types of shocks feature a fall in foreign income, which reduces the demand for domestic firms. But financial shocks also feature an increase in the price of aggregate risk in global financial markets, which makes financing risky firm debt more expensive. This is consistent with the evidence that the risk premium rises in financial crises, whereas the risk-free rate is barely affected. As in previous macroeconomic models, financial frictions amplify both types of aggregate shocks. However, the novel result in my model is that shocks which are financial in nature lead to additional amplification and persistence.

The amplification mechanism is related to the financial properties of intangible capital. I estimate that intangible assets are harder to pledge as collateral than tangible assets. Therefore, in case of default, creditors expect lower recovery rates for intangible-capital intensive firms. Moreover, all firms are more likely to default in bad states of the world. Given these two equilibrium results, the debt of intangible-capital-intensive firms carries more aggregate risk, i.e., its repayment rates covary more with the aggregate state. Hence, financing investment in intangible capital always tends to be more costly than financing tangible investments. Yet, this differential widens when a financial shock hits the economy, as creditors discount aggregate risk more heavily. Consequently, intangible investment falls

disproportionately more after a financial shock. The rise in financing costs also causes an increase in firm default and exit rates, especially for intangible-intensive firms, which entails efficiency losses. Thus, both the intensive and extensive margin propagate the GDP decline.

Indeed, the Spanish firm-level data confirms that the Great Recession came together with a particularly large fall in the debt issuances and investment rates of intangible-capital-intensive firms and industries, a considerable deterioration in several intangible investment and productivity measures, and a surge in firm exit rates. None of these facts can be replicated by a standard model without endogenous intangible investment.

The properties of intangible capital also lead to two channels of persistence. First, I estimate that investment adjustment costs are higher for intangible capital. This implies that entrants replacing exited firms take more time to reach the mature level of intangible capital than that of tangible capital. Second, my model allows for gradual spillovers of intangible capital to other firms in the economy. Such spillovers can take the form of diffusion of knowledge about technological and organizational processes, new products, or domestic and foreign market conditions. Individual firms perceive spillovers of their own intangible capital as private depreciation, but public intangible capital, which accumulates with firms' spillovers, does not depreciate. It is therefore a slow-moving variable that contributes to generate low-frequency fluctuations. As a result, any shock that affects intangibles disproportionately more, such as a financial shock, also causes more persistence.

The quantitative part of this paper estimates the model using a high-quality representative panel of Spanish manufacturing firms from 1990 to 2013, the Survey on Business Strategies (*Encuesta Sobre Estrategias Empresariales*). This dataset is unique in that it features very detailed information on firms' tangible and intangible investment expenditures, together with complete balance-sheet information on assets and liabilities, including the stock of tangible and intangible assets. Intangible investment is disaggregated into R&D, marketing and advertising, technology imports and training of workers, with the first two categories accounting for the largest share. The dataset covers small and medium enterprises, which represent a large share of the market in Europe, and an even larger share of investment and job creation. I complement this sample with information on the entire manufacturing firm population from the Firm Public Registry (*Directorio Central de Empresas*).

The model parameters are estimated by indirect inference, matching key firm-level moments regarding cross-sectional and within-firm patterns of investment and financing. Targeted moments include the tangible and intangible investment rates as a function of firm characteristics and their within-firm volatility, the average leverage ratio across firms, firm life-cycle growth, and aggregate entry and exit rates. In the model, firm heterogeneity is due to the presence of persistent firm-idiosyncratic shocks to the private depreciation of

intangible capital. I infer that intangible assets are less collateralizable from the empirical observation that intangible-intensive firms tend to issue less debt. I also estimate that intangible capital has higher adjustment costs, as the within-firm volatility of intangible investment rates is lower, and that it has a higher private depreciation rate, as intangible investment rates remain high for mature firms. The private depreciation rate of intangible capital disciplines the intensity of the spillover channel.

Importantly, the model approximates the empirical size-weighted leverage distribution across firms. Considering the endogenous response of intangible investment allows for large and persistent effects of financial shocks without assuming unrealistically high levels of external-financing dependence for firms.

Next, I compare model-simulated aggregate data against the evolution of the macro time series in the Spanish manufacturing sector. The model takes the observed dynamics of aggregate prices as given. State prices in financial markets and foreign income shocks are directly estimated with data on the expected equity premium and GDP in the rest of the European Union. Therefore, the comparison with the Spanish macro data serves as an overidentifying check of the model. The simulated model can fit both the extent and the components of the Great Deviation that followed the Great Recession. Specifically, the main drivers of amplification seem to be the new channels described in this paper: lower intangible investment rates by incumbents and higher firm exit rates, together with the fall in employment due to the rigid behavior of wages. In contrast, a standard model of heterogeneous firms and collateral constraints, but no endogenous intangible investment, would miss 58 percent of the observed GDP fall from 2008 to 2013. The spillover channel does not significantly amplify the initial impact of the Great Recession, but it is important for persistence as it almost doubles the predicted deviation of GDP from trend by 2018.

The need to speed up the recovery is at the center of the policy debate in Europe. With this goal in mind, the European Commission is currently starting to implement a policy of subsidized credit to risky investments, the so-called Juncker Plan. This paper proposes an alternative policy that could be more effective in increasing aggregate investment at no public cost: a budget-neutral scheme of transfers based on firm age. Such a policy mitigates the consequences of a financial shock because it relaxes the borrowing constraints of younger firms, which tend to have higher returns to investment in tangible and especially intangible capital, moving the economy closer to the first-best allocation. If implemented unanticipatedly in 2009, this policy could have avoided 15 percent of the 2008-2013 GDP fall, according to the model. Conditioning transfers on firm size is less efficient than conditioning on age, as an important fraction of small firms are not financially constrained. The implementation details of the Juncker Plan are yet to be finalized. However, in a framework with endoge-

nous borrowing constraints, subsidized credit fails to increase the debt capacity of a firm and crowds out private credit. Thus, the current European policy also seems to be dominated by well-targeted outright transfers.

This paper is motivated by the empirical literature on the macroeconomic consequences of financial crises. Muir (2014) documents that periods of financial turmoil are associated with increases in spreads in financial markets, and Gilchrist and Zakrajšek (2012) and Krishnamurthy et al. (2015) show that these increases tend to predict persistent declines in output. Another side of the empirical literature classifies recessions as financial if they come together with episodes of bank restructuring or default. Reinhart and Rogoff (2009) document the persistence of financial recessions across countries and over time, while Jorda et al. (2013) show that financial recessions tend to last longer than non-financial recessions in advanced countries, even conditioning on the magnitude of the fall in output. On the other hand, Bordo and Haubrich (2012) and Romer and Romer (2015) point out that the size of financial recessions reported in previous papers may hinge on the definition of the sample and the recession period. Starting with Bernanke and Gertler (1989), there has been an ample body of research modeling the impact of financial frictions on the economic cycle. Quantitative papers in this literature include Bernanke et al. (1999), Mendoza (2010), Gertler and Karadi (2011), Gertler and Kiyotaki (2013) and Boissay et al. (2015). One common feature of the quantitative analysis in these papers is that the agents that own the productive technology tend to rely more on external financing than what is typically observed in the data. This assumption is necessary for these models to replicate the empirical depth and persistence of financial recessions. In practice, as shown in Shourideh and Zetlin-Jones (2014), most firms seem to have enough internal funding to cover all their investment needs. Since my paper considers the response of an additional investment margin, intangible capital, which is disproportionately affected by financial shocks, it can explain the aggregate consequences of financial shocks while still fitting the distribution of external financing across firms.

A series of papers have considered the effects of financial shocks on aggregate productivity due to misallocation across heterogeneous firms, following on the observation by Hsieh and Klenow (2009) that firm-level returns to capital are highly heterogeneous. Recent contributions to these literature include Buera et al. (2011), Khan and Thomas (2011), Gilchrist et al. (2013), Khan et al. (2014), Midrigan and Xu (2014), Buera and Moll (2015) and Gopinath et al. (2015). However, these papers do not study the endogenous decision of a firm to invest in increasing its productivity. The effects on aggregate productivity that they obtain are caused by compositional changes after exogenous shocks.

Another branch of the literature, stemming from the work of King and Levine (1993) and Rajan and Zingales (1998), has focused on the link between financing and innovation (which

is a form of intangible investment) from both the empirical and theoretical point of view. Aghion et al. (2010) develop a model with two-period firms where the fact that investment in innovation has a longer time horizon can explain why financial recessions are more persistent. Allowing for a lower private depreciation rate of intangibles would amplify the persistence of crises in my model. Yet, both the studies on intangibles by Corrado et al. (2012) and my own estimates show significantly higher depreciation rates for all categories of intangible capital, including scientific R&D, than for physical capital. Thus, I focus on the spillovers of intangible capital to other firms, which decouple (high) private depreciation rates from (low) social depreciation rates, as well as on the financial properties of intangibles. Garcia-Macia (2013), Guerrón-Quintana and Jinnai (2014) and Queraltó (2015) build upon the medium-run business cycle model of Comin and Gertler (2006), which adds business cycle fluctuations to an endogenous growth model, to calibrate the aggregate role of endogenous innovation after financial shocks in recent recessions. In a similar framework adding New-Keynesian elements, Bianchi and Kung (2014), Anzoategui et al. (2015) and Benigno and Fornaro (2015) describe the interaction between endogenous innovation and nominal rigidities or liquidity traps. However, none of these papers analyzes firm heterogeneity, which is an important dimension due to the non-linear effects of collateral constraints. Ates and Saffie (2014) and Schmitz (2015) do include firm heterogeneity in a model with creative destruction and aggregate financial shocks, but they do not consider the collateralizability of different types of capital nor its effects on incumbent firms' incentives to invest and default. Finally, Kerr and Nanda (2014) provide a thorough summary of the latest developments in the field from the microeconomic perspective.

To the best of my knowledge, my paper is the first to analyze the response of incumbent intangible investment to financial shocks in a dynamic framework with endogenous default. In the data, incumbent intangible investment is also sensitive to financial conditions, and it accounts for the largest share of total intangible investment (see Garcia-Macia et al. (2015) for the contribution of incumbents in the U.S.). Moreover, contrary to what simpler innovation models would predict, entry and exit rates are by no means coupled. Both in Spain and in the U.S., the Great Recession brought a surge in exit rates, with a much less obvious (inexistent in Spain) fall in entry rates. Another contribution of this paper to the literature on endogenous productivity is modeling financial shocks as an increase in the price of aggregate risk, as opposed to the risk-free rate or the compensation for default risk. This distinction turns out to be crucial to explain the propagation of financial shocks through the channels related to intangibles and would be missed by a linearized model.

The empirical method in this paper, structural estimation of a heterogeneous-firm model by the simulated method of moments, is similar to the one in Hennessy and Whited (2007),

Bloom (2009) and Acemoglu et al. (2013). The work which is methodologically closer is Eisfeldt and Papanikolaou (2013), which estimates a structural model where firms can invest in tangible and organizational capital, and shows that firms with a larger proportion of measured organizational capital yield a significantly larger equity premium. Nevertheless, Eisfeldt and Papanikolaou (2013) do not study the effects of aggregate shocks nor debt financing. Furthermore, no papers have tried to estimate the relationship between financial constraints and intangible investment in a structural framework with a sample representative of the whole firm population. From the early work on the measurement of intangible assets of Hall (2001), which infers the value of intangibles from stock market valuations, to the studies of Atkeson and Kehoe (2005), McGrattan and Prescott (2005) and Corrado et al. (2009), which use data from national accounts, the focus has been on either publicly listed firms or aggregate data, rather than on smaller firms. Yet, individual information on non-listed firms is crucial to study financial constraints and the extensive entry/exit margin.

There is a series of reduced-form corporate finance studies that corroborate some of the my model's predictions. Benmelech and Bergman (2009) show that asset collateralizability decreases loan spreads and increases lending volumes to firms within the airline industry. With a sample of listed firms, Falato et al. (2013) provide evidence that investment in intangible assets is correlated with own-resource accumulation, which suggests the presence of stricter external financing constraints for those assets. Using an earlier version of the the dataset analyzed in this paper (ESEE), Garicano and Steinwender (2013) show with a diff-and-diff strategy that in the Great Recession domestically-owned firms cut long-run investment by a larger proportion than subsidiaries of multinational firms. Similarly, Aghion et al. (2012) document that French firms which are more credit constrained tend to have a more procyclical R&D expenditures pattern. Goodridge et al. (2013) and Barnett et al. (2014) analyze the striking decline in productivity after the Great Recession in the U.K.

Chapter 2: How Destructive is Innovation?

Innovating firms can improve on existing products made by other firms, thereby gaining profits at the expense of those competitors. Such creative destruction plays a central role in many theories of growth. This goes back to at least Schumpeter (1939), carries through Stokey (1988), Grossman and Helpman (1991), and Aghion and Howitt (1992), and continues with more recent models such as Klette and Kortum (2004). Aghion et al. (2014) provide a recent survey. Other growth theories emphasize the importance of firms improving their own products, rather than displacing other firms' products. Krusell (1998) and Lucas and Moll (2014) are examples. Some models combine creative destruction and quality improvement

by existing firms on their own products – see chapter 12 in Aghion and Howitt (2009) and chapter 14 in Acemoglu (2011). A recent example is Akcigit and Kerr (2015), who also provide evidence that firms are more likely to cite their own patents and hence build on them.

Still other theories emphasize the contribution of brand new varieties to growth. Romer (1990) is the classic reference, and Acemoglu (2003) and Jones (2014) are some of the many follow-ups. Studies such as Howitt (1999) and Young (1998) combine variety growth with quality growth.

Ideally, one could directly observe the extent to which new products substitute for or improve upon existing products. Broda and Weinstein (2010) and Hottman et al. (2014) are important efforts along these lines for consumer nondurable goods. Such high quality scanner data has not been available or analyzed in the same way for consumer durables, producer intermediates, or producer capital goods – all of which figure prominently in theories of growth.[1]

We pursue a complementary approach. We try to infer the sources of growth indirectly from empirical patterns of firm and plant dynamics. The influential papers by Baily et al. (1992) and Foster et al. (2001) document the contributions of entry, exit, reallocation, and within-plant productivity growth to overall growth with minimal model assumptions. We consider a specific growth model with a limited set of parameters. Like us, Lentz and Mortensen (2008) and Acemoglu et al. (2013) conduct indirect inference on growth models with manufacturing data (from the U.S. and Denmark, respectively). They fully endogenize growth, whereas we consider exogenous growth models. The trade-off is that they focus on creative destruction, whereas we further incorporate new varieties and own-variety improvements by incumbents.

We use data on plants from U.S. manufacturing censuses in 1992, 1997 and 2002. Over this period, we calculate aggregate TFP growth, the exit rate of plants by age and employment, employment by age, job creation and destruction rates across plants, growth in the total number of plants, and moments of the employment distribution across plants (the min, median, and mean). The parameter values which best fit these moments lead to three conclusions. First, most growth appears to come from incumbents rather than entrants. This is because the employment share of entrants is modest. Second, most growth seems to occur through quality improvements rather than brand new varieties. Third, own-variety improvements by incumbents loom larger than creative destruction (by entrants and incumbents).

[1] Gordon (2007) and Greenwood et al. (1997) emphasize the importance of growth embodied in durable goods based on the declining relative price of durables.

Chapter 3: Macroprudential Policy with Liquidity Panics

How do firms react to the liquidity shortages generated by financial crises? Does the reaction by firms contribute to disrupt the financial sector? In particular, how do firms' investment decisions influence the equilibrium in the market for interbank loans and viceversa? Understanding the interaction between the supply of liquidity by the financial sector and the demand by firms is key for the analysis of macroprudential policy.

Previous empirical work has documented that firms reallocate their funds toward low-return but more liquid investments during periods of financial instability (see Pinkowitz et al. (2013)). In this paper we show that liquidity hoarding by firms can in turn affect the stability of the financial system, and that the responses of the two sectors can reinforce each other. This feedback loop provides an additional rationale for restrictive macroprudential policy.

We develop a model to study the interaction between the behavior of two groups of agents: firms and banks. Firms face idiosyncratic (short-term) investment opportunities which can only be fulfilled with liquid assets, in the spirit of Kashyap et al. (2002).[2] Firms can hold such liquid assets internally or borrow them from banks (via credit lines or loans). In normal conditions, banks efficiently channel the liquid-asset deposits of households and corporates to firms with profitable investment opportunities. However, banks are subject to informational frictions as in Boissay (2011). First, the lending efficiency of each individual bank is private information. Second, there is moral hazard: banks' shareholders or managers can default on their creditors. Bank heterogeneity gives rise to an interbank market where funds potentially flow from less efficient to more efficient banks, which ultimately lend to firms. Yet, informational frictions might disrupt this market when aggregate economic conditions are unfavorable. When the interbank interest rate is too low, low-efficiency banks have incentives to divert funds borrowed in the interbank market. This leads to an interbank market freeze, where banks stop trading with each other. Such an equilibrium is socially inefficient because low-efficiency banks store their assets in an unproductive technology instead of channeling them to firms.[3]

In response to the possibility of an interbank market freeze and the associated reduction in bank lending, firms may react by accumulating more liquid assets to be able to finance their own shocks. Importantly, this reduces the demand for bank liquidity loans, which lowers

[2]We concentrate on short-term lending because it constitutes the majority of new issuances of bank loans to the corporate sector (see European Central Bank MIR statistics), and therefore is more likely to be affected by temporary financial shocks.

[3]We think that this framework is suitable to study the last financial recession because, according to Brunnermeier (2009), there was a freeze in the intermediation market rather than a run on household deposits.

the interbank interest rate and tightens banks' incentive constraint, making it more probable that an interbank market freeze effectively takes place. Firms react by accumulating even more liquid assets, entering in a feedback loop which we call a "liquidity panic". This novel mechanism leads to multiple equilibria, as a higher level of liquidity accumulation is rational when the probability of a liquidity shortage is higher. Even if we always select the best existing equilibrium, liquidity panics still occur: small aggregate shocks are amplified by the reaction of firms and it takes longer to recover from a crisis.

Bencivenga and Smith (1991) consider a similar economy but without disruptions in the financial sector. The study of self-fulfilling panics in financial markets is pioneered by the bank-run model of Diamond and Dybvig (1983) and extended by Cooper and Ross (1998) and Uhlig (2010) among others. Gertler and Kiyotaki (2013) and Kashyap et al. (2014) consider the liquidity margin embedding bank runs in a general equilibrium model. However, none of these papers study feedback effects from the corporate onto the financial sector. Malherbe (2014) does obtain that a feedback from liquidity accumulation can worsen adverse selection in secondary markets. However, he does not focus on financial intermediaries. On the other hand, Boissay et al. (2015) analyze the macroeconomic effects of crises in a financial intermediation sector with endogenous market freezes, but do not allow for liquidity accumulation by firms. Freixas et al. (2011) show that multiple equilibria also arise when liquidity shocks occur within the banking sector.

The presence of liquidity panics has central implications for the macroprudential policy debate. A common view is that macroprudential policies such as liquidity or capital requirements imply a trade-off between stability and growth or output levels. Such requirements are seen as a buffer that must be accumulated in good times, at the expense of lower investment levels, to eventually cope with financial crises by limiting banks losses or agency frictions. However, we show that this trade-off can disappear once we take into account the reaction of the corporate sector. Policies restricting bank lending, such as stricter liquidity or reserve requirements, can actually end up increasing aggregate productive investment in the economy, even in times of financial stability, as they relieve the agency problems between banks and prevent liquidity panics.

The intuition for this result is as follows. Liquidity requirements oblige banks to set aside a fraction of their portfolio in liquid assets. This has two effects. First, it lowers the supply of interbank loans, which increases the interbank interest rate and reduces the incentives for banks to default on their creditors. This effect by itself reduces the probability of a freeze and thus lowers liquid asset accumulation by firms. But a reduction in liquidity accumulation also increases the demand for bank loans, which further relaxes the conditions for a trade equilibrium in the interbank market. The fall in the probability of a market

freeze reduces inefficient storage in the economy, which is the metric for welfare losses, in a non-linear manner. As a result, a restrictive policy can lead to a higher aggregate productive investment level.[4] Conversely, policies encouraging bank lending in a crises, such as subsidies to the banking sector, can make it harder for the economy to recover from a financial crisis. Such policies increase the supply in the interbank market, which may marginally raise lending to firms in the midst of a liquidity panic. However, an increased supply reduces banks' returns from lending to other banks, which makes it harder to satisfy the conditions for a trade equilibrium and thus to exit the liquidity panic. Combining bank subsidies with negative interest rates on reserves that neutralize the induced increase in the size of the banking sector can be unambiguously welfare improving, but cannot reap the potential amplification gains from preventing an expected liquidity panic.

The literature on macroprudential policy and banking has mainly focused on the moral hazard problem generated by implicit government subsidies to bank debt-holders (Kashyap et al. (2008), Admati et al. (2010), Begenau (2013)). Nevertheless, our model is in line with the view in French et al. (2010) that a central problem during the financial crisis was that disruptions in the financial system's ability to intermediate were the source of panics to other agents in the economy. We show that these panics constitute a crucial factor to consider in the design of optimal policy.

[4]Note that it is never individually optimal for banks to simultaneously borrow and store resources. This policy is only beneficial collectively due to the discontinuous change in the general equilibrium it induces.

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