Financial Shocks and the Real Economy: The Role of Variable Capital

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Abstract

This paper explores the role variable capital in transmitting the effects of a financial shock into the real economy. Variable capital is defined as all advances made by the firm in order to enable production but that, unlike fixed capital, are completely consumed in the production process. If fixed capital is relatively hard to change, the major impact of a shock to the cost of capital will take place through adjustments in variable capital. Estimates based on firm level data show that higher intensity in variable capital is associated with larger drops in sales and that these are larger in industries that have narrow profit margins, so that they have less of an internal cash cushion to draw on in the case of a crisis. Numerical experiments with a calibrated model are able to generate realistic dynamics in output and measured TFP in a one and a two sector economy. The introduction of credit constraints in a two sector model generates interesting dynamics as general equilibrium effects through relative prices gain a more pronounced role in determining allocation and macroeconomic aggregates.

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1 Introduction

Evidence from Sudden Stop episodes using cross industry and cross firm data shows that firms/industries whose production is intensive in variable relative to fixed capital suffer a larger drop in labor and total factor productivity after such shocks. Moreover, the effect is particularly pronounced for firms who are less able to pay for their variable capital needs only out of their internal cash flow. These two findings are evidence that the first major impact of large financial shocks in the real economy is through the cost of variable capital. Simulation of a calibrated dynamic general equilibrium model incorporating the differences between fixed and variable capital is able to replicate some aggregate aspects of sudden stop episodes including the sharp drop and subsequent quick reversal of measured TFP.

Financial crises are notably associated with losses in output, consumption, employment and productivity. While these aggregate effects conform to general economic intuition, the precise channels are somewhat elusive. Calibrated real small open economy models suggest that the effects of interest rate shocks should be small to the extent that firms can substitute capital for labor (Mendoza,1991[1] and Correia et al. 1995 [2]). Moreover, in these models interest rate shocks induce a counter-factual increase in employment. The real business cycle literature on sudden stops has resolved this issue by assuming that, due to some unspecified transactions friction, wages and other variable inputs have to be paid in advance of production (see for example Neymeyer and Perri 2001[3] and Mendoza 2006 [4]). Chari et al. [5] have criticized this approach for relying on "subtle [frictions] for which so far there is little direct evidence." This paper provides direct evidence for a technological aspect that, in itself, is able to generate the required effects[1].

Productivity data also presents a challenge for modelling of financial crises. The drop in productivity after sudden stops is sharp and short lived. The most natural candidate is capacity utilization, understood as variations in the use of short term resources[2]. These variations are typically not accounted for in growth accounting exercises, since they involve variables which are not easy to observe such as the work-week of capital or unobservables such as effort. For emerging markets it is hard to get hold of good data even for the more prosaic work-week of employees. The literature on sudden stops has tried to generate drops in TFP from capacity utilization. The results have been mixed, with some papers claiming success (Gertler et al. 2007[9] and Mendoza 2006[4]) and others not so much (Kehoe and Ruhl 2008[10]). The reason for the mixed results is that the most widely used model of capacity utilization relies

[1] Another issue which is side-stepped in the paper is that the interest rate shock has a positive impact on labor supply through the wealth effect.

[2] Such dynamics exclude explanations based purely on technical progress or regress. Also the evidence on reallocation on the course of crises is not encouraging, with at least a couple of papers finding positive reallocative effects around financial crises (see Borensztein and Lee [6] and Maliranta [7] for analyses of the Korean and Finnish experiences, respectively). Finally, at least when it comes to US data, the evidence for a large role for increasing returns to scale in explaining fluctuations in TFP is tenuous (Basu and Kimball 1997[8]).

on a trade-off between production of goods and of capital. Whether or not such a model is able to generate the requisite drop in utilization will depend on how the relative price between goods capital evolves or on the precise timing of these costs and benefits. The point is illustrated by Kehoe and Ruhl [10] in the context of a two sector model. In their model, while the relative cost of utilizing capacity increases for tradable producers, it decreases for producers of non-tradable goods.

This paper presents theory and evidence to suggest that, in order to generate the key facts about output and productivity from a financial shocks it is enough to require that production takes time, so that there is a time lag between the acquisition of inputs and final sales. The link between the financial shock and measured TFP is established by the natural notion that an increase in the work week of fixed capital or labor is only productive if there is a an increase in the use of variable capital. Thus, a shock to the interest rate will lead to a reduction in the acquisition of variable capital and, given some cost to adjusting fixed capital or labor, a reduction in capacity utilization and TFP.

The simulations also explore implications of the model for an economy with borrowing constraints. These have been proposed as an important element for the understanding of emerging market crises (see for example Gertler et al., [9] and Aghion et al. [11]). The combination of these constraints with the existence of variable capital generates interesting dynamics for output and productivity as entrepreneurs are forced to trade off investment in the two types of capital. In order to keep the role of these interactions clear, the simulation exercises in the current version of the paper side-steps the debt overhang problem emphasized by much of the literature by assuming that firms finance itself with equity[3]. In such a setup, borrowing constraints blunt the impact of the interest rate on the financing costs of the firm. However, in a two sector model they introduce an indirect channel, as movements in relative prices alter the return to investment in different sectors.

The evidence in this paper is also relevant for the literature on inventory cycles and interest rate. This, according to Maccini et al. [13] has had little success in indentifying feedbacks from the interest rate into inventory decisions. While the evidence in the paper does not touch specifically into the behavior of inventories, it provides tangential support to the notion, espoused by Maccini et al., that inventories provide an important channel of transmission for change in the interest rate into the real economy if such changes are perceived by firms. to be of a significant order of magnitude[4].

The paper is structured as follows. The first section sets the scene by presenting a stylized three period model that provides the main intuitions. The second section reviews the empirical evidence presented in studies of sudden stops and presents evidence based on industry and firm level data. The third section sets up the structural model. The fourth section performs numerical exercises to evaluate the ability of the model generating

[3] For a critique of amplification mechanisms based on leverage and debt overhang see Krishnamurthy [12]

[4] Maccini et al. [13] focus rather on relatively small shifts in long term level of interest rate, whereas the evidence in this paper concerns abrupt but not necessarily long lived changes.

some of the stylized facts. The final section concludes.

2 Setting the Scene

2.1 A simple model

To set the scene consider a three period model in which an entrepreneur has to decide how much working capital to invest. While fairly simple, the model will highlight the main mechanisms that will be explored in the course of the paper.

A risk neutral entrepreneur has an endowment e per period. In the first period the entrepreneur choses the amount of fixed capital and the number of employees that he will use. In the second period there is a shock to the interest rate. At this point the entrepreneur choses the amount of materials to be transformed into finished goods and the number of hours that he will require the workers to dedicate to production of that good. Production and consumption take place in the third period. Materials have to be purchased in advance, so that effectively they constitute capital[5]. The production function is

$$y = A \min \{F(uk, hl), n\}$$

Where k is physical capital, l is number of workers, h is the work week of employees, u is the work week of capital and n is the amount of materials used in production. A simplifying assumption that will hold over the whole paper is that the work-week of capital has to be identical to the work-week of employees, so $u = h$. This assumption does not allow for workers to be organized in shifts. While extreme, most of the qualitative results hold so long as the two work weeks are linked in some form. The functional form is akin to Hayashi and Prescott [14] and generalized versions have been used in the empirical work of Basu, 1996 [15]. Under the CRS assumption I can write

$$y = A \min \{hF(k, l), n\}$$

Workers are also risk neutral. They enjoy leisure according function $g(1-h)$ with $g' > 0$ and $g'' < 0$ and are in infinite supply ex-ante. Ex post the entrepreneur and the worker decide on a number of hours for work and bargain on a share of the surplus. Hours worked are chosen so as to maximize total surplus.

Given the risk neutrality assumption, I can write the problem as a surplus maximization problem

[5] The model can accomodate a broader definition of variable capital, including cash held for transaction purposes and trade credit if it has a similar function. For a more thorough discussion of these distinctions, see the empirical section.

$$\begin{aligned} & \max E\left[A\min\left\{h(s)F(k,l),n(s)\right\}+g(1-h(s))l-R(s)b_2(s)\right] \\ s.t. \quad : \quad & n(s)\leq b_2(s)-b_1+e \\ & k=b_1+e \end{aligned}$$

Where s indexes states of nature that are revealed in $t=1$. Only hours, materials and period 2 debt are allowed to depend on s since all other decisions are taken before th shock is realized.

The optimality conditions are

$$\begin{aligned} g'(1-h(s))l &= AF(k,l)-R(s) \\ n(s) &= h(s)F(k,l) \\ 0 &= E\left[AF_k(k,l)h(s)-R(s)\right] \\ E\left[w(s)\right] &= E\left[AF_l(k,l)h(s)\right] \end{aligned}$$

Hours worked decreases with R. The very simple intuition is that hours and materials are complements and that the interest rate is the cost of procuring materials. A more subtle aspect is that the opportunity cost of labor hours does not depend on the interest rate. This is because, first, leisure is not intensive in capital and second the shock to the interest rate does not generate a wealth effect in labor supply. Furthermore, since hours worked and capital utilization are tied to one another, an increase in interest rate will also be associated with a drop in capital utilization.

2.2 Credit Frictions

Suppose now that the entrepreneur faces a borrowing constraint given by

$$R(s)b_2(s)\leq\theta\left[AF(k,l)h(s)-w(s)l+k\right]$$

That is, the entrepreneur cannot pledge more than a fraction θ of future wealth.

There are two possible situations. In one, the borrowing constraint does not bind. In this case the same result as before is obtained. Let h^* satisfy $(A-R(s))F(k,l)=g'(1-h^*(s))l$. The borrowing constraint will bind if

$$F(k,l)h^*(s)>\frac{\theta\left[AF(k,l)h^*(s)+k-w(s)l\right]}{R(s)}-k+e$$

If it does bind, $h(s)$ will be such that the inequality above is satisfied, ie

$$F(k,l)h(s)=\frac{2e-\frac{\theta w(s)l}{R(s)}-\left[1-\frac{\theta}{R(s)}\right]k}{1-\frac{\theta A}{R(s)}}$$

Or still

$$n(s)=\frac{2e-\frac{\theta w(s)l}{R(s)}-\left[1-\frac{\theta}{R(s)}\right]k}{1-\frac{\theta A}{R(s)}}$$

Note that, log-linearizing the expressions:

$$\hat{n}(s) = \left(1 - \frac{\theta A}{R}\right) n\left[-\hat{w}(s)\right]$$

An increase in the interest rate will in general reduce the amount invested in variable capital. The reason is that at a higher interest rate future wealth is discounted more heavily. The effect will be stronger if there is a higher ratio of fixed capital to variable capital and if θ is larger. The intuition for both is the same. An entrepreneur with higher θ or higher k is typically able to finance a higher proportion of his production with external finance. Hence, a shock to the cost of external finance will have a larger impact for such an entrepreneur.

2.3 Implications for measured TFP

It is hard to get reliable data on hours for emerging markets. For that reason, much of the literature that looks at TFP movements during sudden stops (including this paper) do not take fluctuation of hours worked into account. However, TFP movements are large even when hours are taken into account (for example as in Bergoeing et al [16] and the Korean data in the empirical section below). This is because growth accounting exercises typically do not take into account that an increase in the work week of workers will allow for an increase in the work week of capital, so that the elasticity of output to an increase in hours is larger than the elasticity to a proportional increase in the number of employees.

The expected labor share of output is

$$\begin{aligned} E\left[\frac{w(s)\,l}{y(s)}\right] &= \frac{F_L(k,l)\,l}{F(k,l)}\left(1 + cov\left(h(s), \frac{1}{h(s)}\right)\right) \\ &< \frac{F_L(k,l)\,l}{F(k,l)} < 1 \end{aligned}$$

Thus, any growth accounting framework that takes the labor share of output to be a good estimate for the elasticity of output with respect to hours worked will be underestimating its actual effect and will assign part of the effect of fluctuations in hours worked to fluctuations in TFP.

An important remark is that, to the extent that variable capital is primarily accounted for by intermediate input demand, sizeable fluctuations in productivity will not occur if there is no complementarity between variable capital and capacity utilization. This is because standard growth accounting does already take fluctuations in working capital in consideration even if in a crude way, by focusing on variations in value added as opposed to fluctuations in the value produced. To make the point clear, suppose output is given by

$$y = f(k, l, n)$$

And value added is

$$z = f(k, l, n) - n$$

Consider the effect of a change in utilization of working capital on value added, keeping capital and labor inputs constant. To a first order approximation:

$$\hat{z} = \left[\frac{(f_n(k, l, n) - 1)\, n}{f(k, l, n) - n} \right] \hat{n}$$

However, in national accounts, both inputs and outputs are evaluated in the same unit of account. Hence, under perfect competition in input markets

$$f_n(k, l, n) = 1$$

This implies that, absent movements in capacity utilization value added z will, to a first order approximation, not react to variations in the amount of intermediate inputs used.

3 Empirics

This section reviews some empirical regularities of financial crises. I use the same crises dates identified by Calvo et al. [17]. These consist of dates starting from which emerging markets (defined as all countries included in the EMBI+ index) experienced a cumulative output collapse of 4.4% or more and a large reversal in current account Furthermore, they are selected only if they in periods where there is a large increase in the international cost of finance as measured either by Federal Funds rates or the EMBI+ index. The details are spelled out in the paper cited above. These restrictions on the sample imply that the episodes can be reasonably interpreted as generated by shocks to the cost of capital that are exogenous to the internal dynamics of the countries in question. The list of the episodes is in the appendix. They are largely split in three groups: A wave in the early 80s associated with the Volcker shock and the emerging markets debt crisis, a wave in the mid 90's centered around the Mexican crisis and a wave in the late 90's connected to the Asian crisis. The syncronization and wide geographical dispersion of these episodes provide further indication that the main shock was exogenous to these economies. Also, the Asian crises ocurred in the midst of the 90's boom in the US, thus strenghthening the interpretation that these events were likely not driven by productivity shocks spilling over from developed countries..

3.1 Macro-Aggregates

This section presents the behavior of macro aggregates around crises. It replicates some of the findings in the previous literature[6] but also adds observations on employment, average number of hours worked, and change in inventories. The crucial observation is that while hours and inventories

[6] Apart from Calvo [17], see also Tornell and Westermann [18]

react strongly to the crisis and in line with output and TFP, fixed capital and number of employees do not. This provides an indication that the drop in TFP can be reasonably assigned to an incomplete account of the factors of production. Variables are logged and presented as deviations from the peak before the crisis. The graphs plot the median values as well as the first and third quartiles across the sample.

The first graph plots the behavior of GDP. The not very surprising finding, given the way the sample is chosen, is that GDP drops strongly. Three years after the crisis about one half of the countries have recovered to a GDP level close to the peak. While output drops, employment and capital remain roughly on trend, with perhaps a slight deceleration. Median output has yet to catch up with employment three years after the crisis. Capital moves in line with output before the crisis, suggesting that the pre-crisis boom was largely associated with capital accumulation[7]. By the end of the event window, output is converging back to its previous relation with capital.

The second and third graphs together suggest that the crisis periods were largely associated with a temporary drop in productivity of capital and labor. This is confirmed by the fourth graph that shows the behavior of TFP. The financial shock triggers a reduction in productivity of capital and labor.

More to the point of the paper, inventories drop swiftly with output. Hours worked are not easily available in comparable measures across emerging markets. However, the evidence for South Korea confirms that there is a strong swing in the work week of labor, in line with the drop in output. These are evidence that the drop in output can be traced to reductions in at least some variable inputs.

3.2 Cross Industry Performance

In this section I follow a version of the methodology used by Rajan and Zingales (1998) [19]. It consists of using a firm level database with accounting data from listed firms such as COMPUSTAT to construct industry level characteristics and then use industry level data to assess how the charateristics in question were associated with some dimension of industry performance.[8] I will use a similar methodology, but focusing on variables which are more closely related to the question at hand. This methodology has the advantage of taking advantage of the detailed information made available by listed firms while focusing on dependent variables which are

[7] Capital is calculated from gross fixed capital formation using the perpetual inventory method. The depreciation rate is set at 8%. The initial capital stock for the country is set by picking the first observation for gross fixed capital formation and assuming that it was just sufficient to keep capital stock constant on that year. While crude, this method has generated results for TFP which are essentially identical to the ones in Calvo et al. [17] and other studies of sudden stop episodes.

[8] Rajan and Zingales were particularly concerned about the relationship between long run economic growth and financial dependence, defined as the amount of resources that a firm has to borrow from external sources in order to finance investment. The methodology has been applied by Kroszner et al. (2002) in the context of banking crises, with the focus centered around role of financial dependence.

more likely to be representative of the economy as a whole. A necessarty identifying assumption, however is that these listed firms are sufficiently representative that the charasteristics constructed using COMPUSTAT can be taken as valid for the industry as a whole.

After removing outliers I take the medians of the accounting variables below over industries and time. The rationale is that these medians give an indication of technological differences between industries. However, in contrast to Rajan and Zingales, who use only US data, I focus on median values across emerging markets, defined as all countries included in the EMBI+ index. Because the focus of the paper is not on long run relations, the potential endogeneity problems are not as severe as in Rajan and Zingales so long as firms perceive sudden stops to be sufficiently rare. In any case even if such endogeneity is present, it would tend to bias the results in the opposite direction. Furthermore, using the data from the countries under analysis gives a better estimate the characteristics of the industries under consideration.

The focus of the analysis is on the ratio

$$\frac{\text{Variable Capital}}{\text{Total Capital}}$$

Acording to the theory above, total factor productivity will be most sensitive to the interest rate shock when this ratio is high. It is necessary however to identify what is the empirical counter-part for the numerator and the denominator. For the empirical counterpart of total capital, I use net operating assets, defined as Property, Plant and Equipment (net of depreciation) plus working capital (ppent+act-lct in COMPUSTAT). It excludes intangible assets and long run financial investments.

For variable capital, the broadest measure is working capital, given by current assets minus current liabilities (act - lct). Apart from inventories, this includes trade receivables and cash and cash equivalents net of payables and short term debt. This variable is adequate if the major source of money demand by the firm is transactional. If firms have high precautionary motives to hold cash, the high working capital holdings may simply reflect the fact that these firms expect to be vulnerable to shocks Define working capital intensity as

$$WKINT = \frac{\text{Current Assets - Current Liabilities}}{\text{Operating Assets}}$$

The second alternative removes cash and cash equivalents (che) from working capital. It may still be too broad to the extent that, absent financial frictions, firms should be able to change their short term portfolio of financial assets and trade credit without a direct impact on production. It may be to narrow to the extent that cash is kept for transactional purposes, this alternative may miss an important part of the story. This measure is defined as

$$WKNCINT = \frac{\text{Working Capital - Cash and Cash Equivalents}}{\text{Operating Assets}}$$

The third alternative is to include only inventories (invt) in variable capital. While inventories are definetely a form of capital, the status as a factor of production is less clear. This is particularly true for finished goods inventories. Rather, a large part of the literature on inventories suggests that these are held primarily to smooth production and/or sales[20] or in order to avoid stockouts[21]. Such strategic use of inventories may pose endogeneity problems similar to the ones presented by cash, as firms with more variable sales may feel a greater need to keep high inventory levels.

$$INVINT = \frac{\text{Total Inventories}}{\text{Operating Assets}}$$

The last alternative focuses on raw material and work in progress inventories (invrm+invwip). These are more likely than finished goods inventories to be held due to technological constraints on the production process rather than concerns about the variability of demand. This is specially likely if production is hard to adjust in the short run, as assumed in much of the inventories literature, and if the time to adjust production is not shorter than the time needed to procure raw materials. The model proposed in this paper assumes that these two times are in effect identical. The major drawback of this definition is that it does not recognize the variable capital needs of firms in the retail sector. For this reason, the analysis below will focus solely on the manufacturing sector.

$$INVRM = \frac{\text{Raw Materials and Work in Progress Inventories}}{\text{Operating Assets}}$$

Once industry medians medians are calculated, I take industry level data from the UNIDO (INDSTAT3 Rev. 2) database. This database includes manufacturing industry data for a wide range of countries and years, including data on value added, employment, wages and fixed capital formation going back to the early eighties and late seventies for some countries.With this database it is straightforward to construct labor productivity series and possible to produce estimates for changes in TFP[9]. The table in that appendix shows the number of industries for which data is available in each crisis . It includes a wide range of continents and episodes, from the early 80's to the late 90's.

The correlation matrixes provide the main information that can be extracted from the data at this stage. These are correlation between the average drop in TFP for each industry and the different industry characteristics. There are fairly strong negative correlations between industry level performance in the crisis and various measures of working capital intensity.

3.3 Firm Level Data

The COMPUSTAT Global database allows to move from industry to firm level data. The trade-off is that COMPUSTAT is not entirely representa-

[9] The details of how changes in TFP is estimated are discussed in the appendix. In any case, results are fairly robust to the use of labor productivity associated with the maintained hypothesis of slow moving fixed capital.

tive, because it only includes listed firms. Also, COMPUSTAT only has observations starting in the late 80's, and for most firms there are only observations starting in the mid 90's. For this reason, this section focuses on four Asian countries who underwent a Systemic Sudden Stop in the late 90's according to Calvo et al. [17]. The list of countries and years as well as the number of observations for each country is listed in the appendix. The benefit of using the firm level data is that it is possible to explore the within industry variation while controlling for industry characteristics.

In order to exploit the industry level variation, right hand side variables are constructed at the firm level. These are calculated as the median for each firm over all available years before the crisis. The interpretation of these characteristics as reflecting stable technological constraints is a bit less clear as temporary variations in the state of firms asset just before the crisis could have other effects on its perfomance.

Only a small subsection of the firms has data on employment for the crisis year. This makes a TFP calculation such as above not practical since over the crisis firms are likely to shed many jobs..This could introduce a bias in the results as, given relatively sticky capital stock, more labor intensive firms would experience a larger drop in sales. Another important decision is whether to use change in sales or change in production as the dependent variable. In the model there is no distinction between the two, but for firms that hold finished goods inventories this difference is very important. Using production as the dependent variable would tend to bias the results towards finding large effects for firms that usually hold large finished goods inventories, since they would be able to satisfy their declining demand with their inventories. On the other hand, with sales there could be a bias towards not finding much effect for these firms, as the way to reduce holdings of finished goods inventories is to increase sales. The results are reported for sales, which are likely to be a more reliable data as it does not depend on details of inventory valuation close to the crisis date.

The first set of regressions attempts to replicate the results in the previous section within each industry. The only controls are country and industry dummies. All variable capital intensity variables enter with negative sign and in two out of four cases they are significant to a 5% level. The second set of regressions include controls for the number of employees and labor intensity in each firm. These are calculated in the same way as the other variables, by taking the median of pre-crisis observations for each firm. Labor intensity is defined as the wage bill divided by operating assets. Again all signs are negative and two out of four are significant to 5% level. The only dependent variable that remains insignificant in both specifications is intensity in total inventories. This is consistent with the discussion above on potential bias of treating final goods inventories as a variable input in production. Intensity in raw materials ceases to be significant once labor intensity is controlled for. Both variables are correlated (at 32%) and when labor intensity is introduced neither variable is significant, indicating a multicolinearity problem.

The second set of regressions attempts to identify whether the drop in sales can be attributed to the financial shock. An alternative hypothesis is that firms that are intensive in variable capital have more flexible production, allowing them to respond quickly to changing cirucunstance. In order to rule out this possibility, I look at the interaction between the measures of variable capital intensity above and measures of how directly exposed firms are to shocks in external finance.

The chosen measure is markup or profitability. Firms with high mark up can draw more easily on profits to pay for their production costs, since, per definition, these are higher relative to the latter. Define

$$MARKUP = \frac{\text{Sale}}{\text{Production Costs}}$$

Production costs (mnemonic *cogs* in COMPUSTAT) includes cost of materials and sales and excludes capital depreciation. This variable provides a measure of how much slack in cash-flows the firm can typically count with in order to counter a drying out of external finance. Of course, this variable is only a good measure of how exposed firms are to shocks to external finance under the maintained hypothesis that even after the shock the firm would rather retain its internal cash-flows rather than invest them on financial assets.

This variable is closely related but different from the financial dependence measure constructed by Rajan and Zingales. The essential difference is that while Rajan and Zingales were concerned with the ability that firms had to finance capital expenditures from their own cash-flows, this measure captures more generally their ability to do any expenditure on top of its production costs, including possibly variable capital. This is more appropriate for the current context since, as discussed in the previous section, the drop in output after the crisis is unlikely to be related to an inablility by firms of increasing their puchase of fixed capital[10].

In order to avoid potential endogeneity issues, the $MARKUP$ variable is constructed as in the previous section, at the industry level. After that, firms are divided in three equal sized groups acording to how high the $MARKUP$ variable is. The results reported shows the difference in the effect of intensity in variable capital between high and low $MARKUP$ industries, with and without controls for firm size and labor intensity. The marginal effect of working capital intensity is consistenly less negative in high $MARKUP$ industries. The difference is significant at a 5% level when the measure of variable intensity is either based on total inventories or total working capital minus cash.

4 A quantitative model

The next step is to build a quantitative model in order to assess whether, from a theoretical stand-point, the presence of variable capital enables the macro dynamics described above. Apart from the introduction of variable capital in the production function the model has a few other

[10] The variable used by Rajan and Zingales is capital expenditure (COMPUSTAT mnemonic *capx*). This includes primariliy additions to property plant and equipment but no change in inventories or other forms of working capital.

non-standard features. First, in order to be able to generate changes in capacity utilization, the work week of capital is constrained to be equal to the work week of workers as in section 2 Second, in order for the work week of labor to be an important margin of adjustment, employment has to be hard to adjust. This is modelled with a Mortensen-Pissarides [22] style labor market. Third,households live in perpetual youth and die in any given period with positive probability. This assumption is made to keep household debt well defined in steady state

There are two extensions of the model. The first is the introduction of a non-tradable sector. This is done by assuming that firms are split in producers tradable and non-tradable inputs, which in turn are combined to produce consumption goods as well as fixed and variable capital. This extension allows to assess the robustness of the model to the Kehoe and Ruhl [10] effect, in which the drop in capacity in the non-tradable sector is offset by an increase in capacity in tradables.

The second extension is the introduction credit constraints. These are motivated by assuming that firms are run by entrepreneurs who are unable to commit fully to repayment of obligations. These entrepreneurs also live in perpetual youth, so that in steady state there is a wedge between the marginal productivity of capital and the interest rate. This extension is motivated primarily by the widespread use of credit frictions in the sudden stop literature. It implies interesting dynamics to the extent that they retard sectoral reallocation in the two sector model, thus allowing consumption decisions to play an important role.

4.1 Workers

There are large, infinitely lived families that whose resources are managed centrally by a family head who cares about all members. Families end with probability $1-\varphi$, at which point they are replaced by new families. This assumption is introduced in order to keep the debt of families stationary. Family members are endowed with labor that they can offer to entrepreneurs through a search market. They enjoy utility of leisure as given by the function

$$\begin{aligned} g(1-h) &= \chi_u \text{ if } h=0 \\ g(1-h) &= \chi_e \frac{(1-h)^{1-\frac{1}{\psi}}}{1-\frac{1}{\psi}} \text{ if } h>1 \end{aligned}$$

Period utility for a family member is given by

$$u(c+g(1-h))$$

This form is similar to the one adopted by Greenwood et al [23] and is common in the small open economy RBC literature. One interpretation is that the utility of leisure stands in for the production of home goods which, in turn, are perfect substitutes to the consumption good produced by firms. More to the point this utility function assumes away any wealth effects on the cost of labor hours. It is well understood that such wealth effects are incompatible with the drop in labor hours and employment during financial crises, since they create incentives for households to work harder (see Mendoza 1991[1], Neumeyer and Perri 2004 [3] among others). Removing these effects keeps the focus on the decisions of the firms.

Because all members of the family are treated equally, the period utility of the head of the family can be written as

$$u\left(c+g\left(1\right)\left(1-l\right)+g\left(1-h\right)l\right)$$

Families can buy annuities in the international market. However, following much of the tradition in small open economy models, families cannot trade in state contingent assets other than that. This will imply that a shock to the interest rate will be perceived as a shock to wealth and will have an impact on consumption.

In equilibrium, the family is always better off if more of its members work. All of its members who do not have a job search for work. In any given period $\Psi\left(V,1-L\right)$ matches are made, where capital letters refer to aggregate variables which are taken as given by the family. Matched family members bargain with employers and settle on number of hours worked h and a wage w. Matches are destroyed with probability δ_L.

The value function for the family can be written as

$$\begin{aligned} W\left(a,l\right) &= \max_{c,a'} u\left(c+g\left(1\right)\left(1-l\right)+g\left(1-h\right)l\right)+\beta\varphi E\left[W\left(c',a',l'\right)\right] \\ s.t. &: \quad c+a'=\frac{R}{\varphi}a+wl \\ & \quad l'=\left(1-\delta_L\right)l+\frac{\Psi\left(V,1-L\right)}{1-L}\left(1-l\right) \end{aligned}$$

The consumption/savings decision will accord to the usual euler condition

$$u'\left(z\right)=\beta RE\left[u'\left(z'\right)\right]$$

With

$$z\equiv c+g\left(1\right)\left(1-l\right)+g\left(1-h\right)l$$

The marginal value of a match for the family is given by the envelope condition

$$W_l\left(c,a,l\right)=u'\left(z\right)\left[w+g\left(1-h\right)-g\left(1\right)\right]+\left(1-\delta\right)\beta E\left[W_l\left(c',a',l'\right)\right]$$

4.2 Entrepreneurs

Entrepreneurs are not part of families. They live by their own, in perpetual youth and die with probability $1-\pi$ in any period. This assumption will be important once credit constraints are introduced, since it will allow the marginal productivity of capital to be above the interest rate in steady state. Entrepreneurs learn about their death in the beginning of each period. They have time to take to term whatever production decision was taken in the previous period, sell off their production and assets to other entrepreneurs and consume the proceeds. Entrepreneurs control three technologies. The first is a goods production technology. It is given as in section 2 by

$$A\min\left\{F\left(k,l\right)h,n\right\}$$

Where k is the amount of physical capital, l is the number of employees and n is the amount of materials used in production and F is CRS. The second technology allows them to produce capital goods. It is given by

$$\begin{aligned}&\kappa\left(i,k\right)\\&\kappa'>0,\ \kappa''<0\end{aligned}$$

Where i is gross investment and κ CRS. This technology allows for convex adjustment costs. These are introduced in order to keep accumulation of physical capital slow, in contrast to the fast moving working capital.

Last, they have access to a search technology. This allows the entrepreneur to initiate relationships with workers that provide good matches for their production techniques. If in the beginning of a period they have relationships with l workers, by the end of the period a fraction δ_L of these will be dissolved for exogenous reason. If they invest v units of consumption good in searching for new workers they will form $\frac{\Psi(V,U)}{V}v$ new relationships.

All assets can be traded among entrepreneurs. In particular, this is true for relationships with workers. One interpretation is that relationships are specific not to the entrepreneur but to a particular blueprint that only the entrepreneur has access to. To the extent that this blueprint can be sold to other entrepreneurs, workers can change employers without changing jobs. These transactions are akin to the change in ownership of a firm or part of a firm. The new owner inherits the production blueprints and the relationships with all existing workers. Note that capital is not specific to the blueprint, so that workers and capital can be separated.

The value function of the entrepreneur is given by

$$\begin{aligned}J\left(b,n,k,l\right) &= \max_{c,n',k',l',i,v} u\left(c\right)+\beta E\left[\pi J\left(b',n',k',l'\right)+\left(1-\pi\right)u\left(\Omega\left(b',n',k',l'\right)\right)\right]\\ s.t. &: c+n'+q_k k'+q_l l'+Rb+v+i+wl\\ &= A\min\left\{F\left(k,l\right)h,n\right\}+q_k\kappa\left(i,k\right)+q_l\left(\left(1-\delta_L\right)l+\frac{\Psi\left(V,U\right)}{V}v\right)+b'\\ \Omega\left(b,n,k,l\right) &= \max_{i,v}\left\{A\min\left\{F\left(k,l\right)h,n\right\}+q_k\kappa\left(i,k\right)+q_l\left(\left(1-\delta_L\right)l+\frac{\Psi\left(V,U\right)}{V}v\right)-i-wl-v-Rb\right\}\end{aligned}$$

The optimality conditions for the entrepreneur are

$$
\begin{aligned}
&u'(c) = \beta RE\left[\pi u'\left(c'\right) + (1-\pi)\, u'\left(\Omega\left(b', n', k', l'\right)\right)\right] \\
&1 = q_k \kappa_i (i, k) \\
&1 = q_L \frac{\Psi(V, U)}{V} \\
&n = F(k, l)\, h \\
&q_l + F_l(k, l)\, h = E\left[\frac{(1-\delta_L)\, q_l' + A' F_l(k, l)\, h - w}{R}\right] \\
&q_k + F_k(k, l)\, h = E\left[\frac{\kappa_k(k, i)\, q_k' + A' F_k(k, l)\, h}{R}\right]
\end{aligned}
$$

The first condition is the euler equation for the entrepreneur. The latter two conditions equate the marginal cost of acquiring capital or employment relationships from other entrepreneurs with the cost of producing them in house. The third condition stems from the Leontieff assumption and states that variable capital has to be proportional to output. The last two conditions are the euler conditions for acquisition of labor and capital respectively. When calculating the cost of expanding in either of these dimensions the entrepreneur takes into account that such expansion can only be productive if he increases the amount of working capital n.

The marginal value of an employee is

$$J_l(b, n, k, l) = u'(c)\left[AF_l(k, l)\, h + (1-\delta_L)\, q_L - w\right]$$

4.3 Wage bargaining

Wage is set by Nash bargaining between the entrepreneur and the worker. Wage and hours of work are chosen in order to solve

$$\max \left[\frac{W_l(a, l)}{u'(c^w)}\right]^{\mu} \left[\frac{J_l(b, n, k, l)}{u'(c^e)}\right]^{1-\mu}$$

In words, hours and wage are chosen such as to maximize a geometric average of the marginal benefits to the different parts of the employment relationship. These are normalized by the respective marginal utilities of consumption, so that they are valued according to the numeraire good. The parameter μ reflects the bargaining power of the worker. Using the envelope condtions and the first order conditions for the problem of the entrepreneur, the wage will be given by

$$w = \mu AF_l(k, l)\, h + (1-\mu)\left[g(1-h) - g(1)\right]$$

Hours will be chosen in order to maximize the total surplus. The choice of hours will take into account not only the trade-off between leisure and work, but also the fact that additional hours are only productive if the appropriate amount of materials is bought in advance. The optimality condition is

$$F(k,l) = E\left[\frac{AF(k,l) - g'(1-h)}{R}\right]$$

This last relation represents the core of the mechanism under consideration. Hours worked depend negatively on the interest rate.

4.4 Tradables and Non-Tradables

The framework above accomodates a two sector model, with tradables and non-tradables. For that purpose, assume that only the goods produced by some entrepreneurs are tradables, whereas the others have to sell their goods in the domestic market. The ability to trade goods in foreign markets is specific to the entrepreneur but not to the capital they use or the employment relationships that they hold. This implies that capital and employment relationships can move freely between entrepreneurs in different sectors.

The goods produced by entrepreneur are used in turn as inputs for the production of consumption, investment, search or intermediate goods. These different goods are assembled according to the production functions

$$\begin{aligned}
c &= \left[\gamma_C^{-\frac{1}{\rho}}\left(x^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_C)^{-\frac{1}{\rho}}\left(x^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
i &= \left[\gamma_I^{-\frac{1}{\rho}}\left(x^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_I)^{-\frac{1}{\rho}}\left(x^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
n &= \left[\gamma_N^{-\frac{1}{\rho}}\left(x^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_N)^{-\frac{1}{\rho}}\left(x^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
v &= \left[\gamma_V^{-\frac{1}{\rho}}\left(x^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_V)^{-\frac{1}{\rho}}\left(x^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}
\end{aligned}$$

Let the tradable good be the numeraire and s the relative price of the non-tradable good. Cost minimization implies the following price indices

$$\begin{aligned}
p_C &= \left[\gamma_C + (1-\gamma_C)\, s^{\rho-1}\right]^{\frac{1}{\rho-1}} \\
p_I &= \left[\gamma_I + (1-\gamma_I)\, s^{\rho-1}\right]^{\frac{1}{\rho-1}} \\
p_N &= \left[\gamma_N + (1-\gamma_N)\, s^{\rho-1}\right]^{\frac{1}{\rho-1}} \\
p_V &= \left[\gamma_V + (1-\gamma_V)\, s^{\rho-1}\right]^{\frac{1}{\rho-1}}
\end{aligned}$$

The problems of the entrepreneur and the working families remain unchanged, except that now the different goods enter the budget constraints preceded by the corresponding price indices and the revenue from sales of non-tradable goods takes into account the relative price of non-tradables s. The optimality and bargaining conditions become

$$u'(c) = \beta RE\left[u'(c')\frac{p_C}{p'_C}\right]$$

$$\begin{aligned}
&\frac{u'(c)}{p_C} = \beta RE\left[\frac{\pi u'(c') + (1-\pi)\, u'(\Omega(b', n', k', l'))}{p'_C}\right] \\
&p_I = q_k \kappa_i (i, k) \\
&p_V = q_L \frac{\Psi(V, U)}{V} \\
&n = F(k, l)\, h \\
&q_l + p_N F_l (k, l)\, h = E\left[\frac{(1-\delta_L)\, q'_l + \sigma' A' F_l (k, l)\, h}{R}\right] \\
&q_k + p_N F_k (k, l)\, h = E\left[\frac{\kappa_k (k, i)\, q'_k + \sigma' A' F_k (k, l)\, h}{R}\right]
\end{aligned}$$

$$\begin{aligned}
F(k, l) &= E\left[\frac{\tilde{s} AF(k, l) - p'_C g'(1-h)}{R}\right] \\
w &= \mu \sigma AF_l (k, l)\, h + (1-\mu)\, p_C \left[g(1-h) - g(1)\right]
\end{aligned}$$

With

$$\begin{aligned}
\sigma &= 1 \text{ if entrepreneur is in tradable sector} \\
\sigma &= s \text{ otherwise}
\end{aligned}$$

4.5 Borrowing Constraints

The sale of assets as well as any output produced by the entrepreneur requires some transmission of expertise to the buyer. Such transmission can be verified, but it cannot be enforced since, in the language of Hart and Moore, expertise is inalianable. This implies that the sale of assets can occur in a spot market, but entrepreneurs cannot commit to transmitting them in the future.

In this case, when planning future production and purchasing the requisite assets, the entrepreneur is able to convey part of the expertise necessary to enjoy full benefit of the output that will be produced. With that expertise, the outsider is able to capture a fraction θ of the output in the following period.

Ex-post entrepreneur and outsider bargain about the division of the output. This takes place after output is produced, which is to say, after wages and investment are paid for. The bargaining protocol is as follows: The entrepreneur makes a take it or leave it offer to outsiders. These in turn are able to walk away from any offer with full control of all property owned by the entrepreneur. After bargaining is concluded the relationship between entrepreneur and financier is terminated and any records about the negotiatio are erased. The entrepreneur will thus under all states of nature offer a fraction θ of all goods in his possession and the outsiders will accept it. This contract has the structure of an equity contract. Note that, under this formulation, there is no possibility of monetary mismatches or debt overhang driving the response to interest rate shocks.

The contract induces the borrowing constraint

$$R'b' \leq \theta E\left[A' \min\left\{\phi\left(\frac{k'}{l'}\right) lh, n\right\} + q^K \kappa\left(\frac{i'}{k'}\right) k' + q^L\left[\left(1-\delta_L\right) l' + \frac{\Psi\left(V,U\right)}{V} v'\right] - v' - w'l' - i'\right]$$

Note that if $\theta = 1$ the credit friction disappears as the entrepreneur will be able to pledge essentially all his future wealth. If, however, $\theta = 0$, all finance is done through retained profits.

If borrowing constraints bind, all the conditions above remain as before, except that the discount rate used by the entrepreneurs change. Namely, instead of given by the inverse of the international interest rate R, the discount rate becomes

$$\frac{1}{\tilde{R}} = \frac{\theta}{R} + \left(1-\theta\right)\frac{p_C}{p'_C}\left[\left[\pi\beta\frac{u'\left(c'\right)}{u'\left(c\right)} + \left(1-\pi\right)\beta\frac{u'\left(\Omega\left(b',n',k',l'\right)\right)}{u'\left(c\right)}\right]\right]$$

The discount rate is the weighted average of three components. The first reflects the discount rate of lenders, which is just the inverse of the interest rate. Its weight is equal to the fraction of output that will be received by lenders. The second and third reflect the intertemporal trade-off faced by the entrepreneur. With probability π the entrepreneur survives, in which case his consumption will be c', but with probability $1-\pi$ he does not, in which case he consumes all his wealth. The first term can be interpreted as the cost of external finance, whereas the second and third terms reflects the cost of internal finance.

In the presence of binding borrowing constraints it is important to keep track of the evolution of entrepreneurial wealth. This will be given by the flow of funds constraint that they face. The borrowing constraint will bind so long as $E\left[\frac{R}{\tilde{R}}\right] \leq 1$

4.6 Aggregation and Market Clearing

Aggregation can be achieved under the assumption of homothetic preferences together with constant returns to scale technologies. Under these assumptions, consumption, input choices and output are all linear in wealth. Aggregate variables will be designated by capital letters, whereas small letters will be used for individual variables. Primed small letters will, as before, denote the (possibly state contingent) decisions made about the future by existing individuals, but the capital letters will incorporate the decisions of newly born ones.

First consider the consumption of families. Since families do not age, their human wealth is identical and equal to Λ, where Λ satisfies the recursive relation

$$E\left[\frac{\Lambda'}{\frac{R}{\varphi}}\right] = \Lambda - \sum w^s L^s$$

s indexes the sector in which different family members are working in.

Consumption of families is given not only by what they purchase in the market, but also by their leisure (or home production) and is denoted as above by z. It is proportional to their wealth. With homothetic preferences, the Euler condition for families can be written as

$$1 = \beta R E\left[u'\left(\frac{z'}{z}\right)\right]$$

In aggregate, $z = Z$. However, since there will be new families entering in next period, z' is a fraction of total consumption Z

$$z' = \frac{\varphi\left(\Lambda' - \frac{R}{\varphi}B'\right)}{\varphi\left(\Lambda' - \frac{R}{\varphi}B'\right) + (1-\varphi)\Lambda'} Z'$$

Entrepreneurs do not own human wealth. However, if they face borrowing constraints, they need to endowed with some wealth when they are born. This will be ω_0. Their consumption euler equation is

$$1 = \beta E\left[\tilde{R}\left[\pi u'\left(\frac{c'}{c}\right) + (1-\pi) u'\left(\frac{\Omega(b', n', k', l')}{c}\right)\right]\right]$$

Since newly born entrepreneurs have essentially zero wealth, it follows that

$$C' = \pi c'$$

The euler equations for factor choices remain all as before with capital letters substituting for the small caps.

The market clearing conditions are

$$\begin{aligned}
Z - \sum g(1-h^s) L^s + g(1)(1-L) + \sum C^s &= \left[\gamma_C^{-\frac{1}{\rho}}\left(X_C^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_C)^{-\frac{1}{\rho}}\left(X_C^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
I &= \left[\gamma_I^{-\frac{1}{\rho}}\left(X_I^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_I)^{-\frac{1}{\rho}}\left(X_I^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
N &= \left[\gamma_I^{-\frac{1}{\rho}}\left(X_N^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_V)^{-\frac{1}{\rho}}\left(X_N^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
V &= \left[\gamma_V^{-\frac{1}{\rho}}\left(X_V^T\right)^{\frac{\rho-1}{\rho}} + (1-\gamma_V)^{-\frac{1}{\rho}}\left(X_V^{NT}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
X_C^{NT} + X_I^{NT} + X_V^{NT} + X_N^{NT} &= A \min\left\{F(K_{NT}, L_{NT}) h_{NT}, N_{NT}\right\}
\end{aligned}$$

4.7 Non Stochastic Steady state

In steady state

$$\begin{aligned} Z' &= Z \\ K' &= K \\ C' &= C \end{aligned}$$

Also, normalize $w = s = 1$.

From these it is straightforward to show that in all sectors

$$\frac{1}{\beta\tilde{R}} = \frac{1}{\beta R}\theta + (1-\theta)\left[\pi u'\left(\frac{1}{\pi}\right) + (1-\pi)\,u'\left(\frac{\Omega\,(B,N,K,L)}{C}\right)\right]$$

Since $\pi < 1$ and $\Omega\,(B,N,K,L) > C$,

$$\pi u'\left(\frac{1}{\pi}\right) + (1-\pi)\,u'\left(\frac{\Omega\,(B,N,K,L)}{C}\right) < 1$$

Thus if $\beta R = 1$

$$\frac{1}{\tilde{R}} < \frac{1}{R}$$

In steady state the discount rate of entrepreneurs will be higher than the foreign interest rate, so that the borrowing constraint will bind. The solution method consists of performing a first order approximation around the steady state[11]. So long as the economy remains close enough to steady state, the assumption of binding constraint is without loss of generality.

5 Calibration and quantitative exercises

In order to calibrate the model, assume the following functional forms

[11] I solve the model using Dynare v.4

$$
\begin{aligned}
F(k,l) &= k^{\alpha} l^{1-\alpha} \\
\kappa(k,i) &= \left[1+\delta_K\left[\frac{\zeta}{1-\zeta}\left(\frac{i}{\delta_K k}\right)^{\frac{\zeta-1}{\zeta}}-1\right]\right] \\
u(c) &= \frac{c^{1-\sigma}}{1-\sigma} \\
g(1-h) &= M+\chi\frac{(1-h)^{1-\frac{1}{\psi}}}{1-\frac{1}{\psi}} \\
g(1) &= M+\omega\frac{\chi}{1-\frac{1}{\psi}} \\
\Psi(V,U) &= \Xi V^{\lambda}(1-L)^{1-\lambda}
\end{aligned}
$$

The parameter M is introduced to make sure that leisure is positive in steady state. It is chosen so that remaining leisure time for a worker is worth roughly 20% of her income. The calibrations are presented in the table below. The non-standard parameters which are central to the model are the rate of production to inputs A and the probability of death of an entrepreneur. I set $A = 2$, reflecting the observation that, for most countries, aggregate value added is roughly half of the value produced, where the difference between the two is accounted for the production of intermediate inputs. The probability of death of an entrepreneur is chosen so that the steady state rate of return on entrepreneurial investment is 9% a year. This is calculated taking the median spread between deposit rates and the rate charged to prime borrowers in emerging markets[12]. The mapping is adequate if entrepreneurs de facto are able to get as much finance as they want, only at the higher rate. In this case the spread would provide a measure of the wedge between the cost of capital for a typical, low risk entrepreneur and the cost of deposits. However, more realistically the entrepreneurs face and upward sloping interest rate schedule, more akin to the one in the model. In that case, the spread used in the callibration is a lower bound.

For most of the other parameters I use calibrations taken from other papers in the literature. In particular, the labor market parameters are taken from Andolfatto (1996) [24] and the shares of tradables and non-tradables are taken from Kehoe and Ruhl (2008) [10]. Also steady state interest rate is 4% a year and β is such that $\beta R = 1$ in steady state. The elasticity of value added to capital α is chosen so that the labor share of income is $\frac{1}{3}$. The two will not be the same, since entrepreneurs have to be compensated for advancing working capital. Finally, in order to focus the interpretation of the results on the effects of inventory behavior, I impose the Hosios [25] condition on the bargaining power of workers, thus assuring that the labor market dynamics conforms to that of a planned economy[13].

[12] This data is available in the World Developing Indicators database.

[13] While results do not look as clean with, say, equal bargaining shares, they are essentially the same.

Finally, for experiments using credit constraints, I calibrate θ so that the credit to private entrepreneurs/GDP ratio will be equal to 50%, which is in the ball park of the deposit bank credit to the private sector to GDP ratio in emerging markets. This implies a fairly low θ, of around 8.5%.

Most of the exercises are done without adjustment costs to capital. When introduced, they will be such that the elasticity of investment/capital ratio to the price of capital relative to that of investment is equal to 2.

5.1 The one sector economy

The first simulation exercises are performed in the context of a one sector economy without credit frictions or adjustment costs to capital. On impact there is substitution of capital for labor, generating a rise in employment. This is compounded by the adjustment costs to employment implicit in the search technology, which makes the rise in employment persistent. In spite of that, output and TFP drop on impact and then converge back to steady state due to the loss in fixed capital and hours. Output and TFP converge back to steady state along.on an exponential path, fairly much in line with the movement in the interest rate. The drop in output and TFP are extremely large, in effect much larger than in actual sudden stop episodes. There is no sign of a v shaped recovery pattern followed by a slower convergence as in the data.

The results look more realistic if ajdustment costs to capital are introduced. Employment drops on impact and there is a noticeable v-shape pattern followed by some stagnation on TFP. This reflects the difference in adjustment times for variable and fixed capital. Also the drop in output is within the ball park of what was experienced by economies who were exposed to sudden stops, at around 7%. The simple one sector model without credit frictions but with adjustment costs to capital appears to do a fairly good job in replicating some the major stylized facts.

One interesting metric is the wedge in hours demand implied by the complementarity with variable capital. This is defined as

$$\begin{aligned} \tau_w AF(k,l) &\equiv AF(k,l) - g'(1-h)\,l \\ &= RF(k,l) \end{aligned}$$

Where the second equation follows from the FOC of the entrepreneur. It follows that in the frictionless economy the wedge is proportional to the interest rate. This wedge induces part of the reduction in hours and TFP observed during the crisis.

The v-shape in output and TFP reflect the slow adjustment of fixed capital. The reason is that in the model, capacity utilization is higher whenever labor productivity is high. Thus, TFP movements occur not only as a response of the wedge induced by the interest rate, but also by movement in capital. In the beginning the dominant force is the wedge, as the interest rate is high, and the mean reversion of the interest rate drives the mean reversion of TFP. Later on the level capital stock remains low for long, keeping TFP depressed after the initial convergence.

Not much happens in an economy with credit constraitns. The calibration implies a very low ratio of external to internal finance. This implies that entrepreneurs will not respond much to shocks in the interest rate, as that responds for only a small fraction of their cost of capital. This is also true if adjustment costs are allowed for. Such costs could in principle allow for a similar mechanism to the one in Kiyotaki and Moore [26] to operate. However since all entrepreneurs are equally little exposed to the interest rate shock, there is not enough drop in investment to generate an substantial amplification mechanism through capital and collateral.

5.2 The two sector economy

The main purpose of this section is to inquire into how robust is the drop in TFP predicted by the model to the introduction of a multi-sector economuy. In a similar setting Kehoe and Ruhl [10] have found that it is hard to generate a significant drop in TFP from capacity utilization because while the non-tradable sector choses to economize capacity, the tradable sector choses to expand its use, so that the net effect is small or ambiguous.

The aggregate variables for this economy look very similar to the one sector economy. This is because while aggregate labor and capital may be hard to adjust, there is almost no constraint on sectoral readjustment. The sectoral allocation is accordingly very volatile and moves in such a way as to keep the relative price of non-tradables constant throughout. The only exception is the first period, the reason being that the sectoral allocation of labor and capital has to be decided with one period in advance. With perfect factor mobility, the marginal productivity of labor is identical in both sectors, and so are hours and TFP.

The only notable difference with the one sector economy is that, because sectoral reallocation can only occur after one period, in the period of the shock the drop in investment and consumption induce a drop in the exchange rate. This reduces the price of capital and keeps labor productivity high for longer. In the model with adjustment cost thiseffect is sufficient to generate a short boom in capital/labor ratio and TFP.

5.3 Two sectors with credit constraints

Credit constraint acquire an interesting role in the two sector economy. The initial channel is through consumption. Household consumption drops with the interest rate shocks, driving down the relative price of non-tradables. This movement is persistent, as the credit constraint slows down the equalization of marginal productivities of capital and labor across the two sectors. Moreover since investment goods are partly non-tradable, this movement in relative prices feeds into the price of capital, generating amplification.

In this setup, the opportunity cost of investment in variable capital is given by the marginal productivity of fixed capital. Linearizing the conditions for capital and hours around the non-stochastic steady state taking the decisions of the entrepreneurs as given generates approximations for changes in the rates of return on fixed and variable capital:

$$\begin{aligned}\hat{R}^k &= (1-\delta)\,\hat{q}_k' - \hat{q}_k + \delta\left(\frac{A}{A+R}\hat{\sigma}' - \frac{R}{A+R}\hat{p}_N\right)\\ \hat{R}^n &= \frac{A}{A+R}\hat{\sigma}' - \frac{R}{A+R}\hat{p}_N\end{aligned}$$

Where

$$\begin{aligned}\hat{\sigma} &= \hat{s} \text{ for non-tradables}\\ \hat{\sigma} &= 0 \text{ for tradables}\end{aligned}$$

The rate of return on fixed capital is given primarily by the expected movements in its price, whereas for variable capital it depends only on the difference between the expected sales price and the price of inputs. Thus, the entrepreneur will chose low investment in variable capital whenever the price of fixed capital is expected to rise. This is precisely what happens on the onset of the crisis. As consumption and investment drops, the price of fixed capital becomes very low. However, the mean reversion is quick, as sectoral allocation adjusts in response to the incentives given by the new set of relative prices. This implies a very high return on fixed capital, which leads to a drop in variable capital, hours and measured TFP.

The rate of return on variable capital is given primarily by the difference between the price of output and the price of variable capital. This will be different for entrepreneurs in the different sectors. The change in the price of working capital $\hat{p}_N$ is approximately an average between the change in the price of non-tradables and the price of tradables. Hence, if the relative price of non-tradables is at least somewhat persistent, the return on variable capital will be high for producers of tradable when the relative price of non-tradables is low and vice versa. This implies that TFP in the tradable sector will be higher than that of the non-tradable sector whenever the price of non-tradables is low, the opposite being true when it is high. This effect will imply that capacity utilization will increase in the tradable sector a little after the crisis, as in Kehoe and Ruhl [10]. However, due to the first effect, it is still low enough that, on net, TFP drops.

The model generates a mild dampened oscillation as the relative price of non-tradables overshoots its long-run level, reflecting the continuing imbalance between the two sectors. After only a few periods, TFP in the tradable sector is above steady state as entrepreneurs in that sector take advantage of the cheap inputs. The rapid capital accumulation in the tradable sector the drop in output and TFP is short-lived. After about two years, TFP turns positive in the non-tradable sector as well. Essentially, the boost to the tradable sector promoted by cheap inputs leads to a relative scarcity of non-tradable goods and a high price of capital. The precise reverse dynamics as before ensues, but only more dampened.

6 Summary and Conclusion

The simple addition of variable capital to a small open economy real business cycle is able to generate many of the dynamic responses to interest rates found in the data, including drops in measured TFP. Unlike assumptions about transactions technologies made in previous papers, this addition has the advantage of being based on a readily measureable quantity, the intensity of variable capital in the production function of firms. Analysis of industry and firm level data around sudden stop events reveals that this is a plausible channel. First industries/firms which are intensive in variable capital experience a larger drop in productivity and sales in the crisis years. Second, this drop appears to be particularly large for firms in industries where typically markups are high. This second finding is interpreted as implying that firms are able to rely on internal funds are going to perceive a less intense increase in the cost of capital during the crisis. This finding helps to rule out a demand channel to explain the correlation between working capital intensity and reaction to the financial shock.

Simulations of a dynamic general equilibrium model gives some extra insight on how the financial shock feeds into the economy when variable capital is an important input. With the presence of adjustment costs to capital, the model is able to generate fairly realistic dynamics in response to the financial shock. The addition of non-tradables in combination to the adjustment cost generates a counter-factual spike in output after the crisis. This spike disappears if credit constraints are allowed for. Moreover, such credit constraints generate interesting dynamics, since in such an economy the opportunity cost of variable capital is given primarily not by the interest rate but by the dynamics in the relative price of non-tradables.

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7 Appendix

In order to construct industry level measures of TFP change, start from the capital accumulation equation:

$$K_{t+1} = (1-\delta)\,K_t + I_t$$

Rewrite this as

$$\begin{aligned} \frac{K_{t+1}-K_t}{K_t} &= \frac{I_t}{K_t} - \delta \\ &= \left[\frac{I_t}{\delta K_t} - 1\right]\delta \end{aligned}$$

The major problem is to have a reliable measure of K_t. However, the time series for investment in UNIDO are relatively short and subject to changes in methodology, so that applying the perpetual inventory method is impractical. Rather, the idea is to use a short series of recent observations on investment to estimate δK_t. Close to steady state

$$I_t \cong \delta K_t$$

So that if the economy was not too far away from steady state investment in recent periods,

$$K_t \cong \frac{1}{\delta}\frac{\sum_{s=1}^{S} I_{t-s}}{S}$$

The depreciation of capital was set to 8% for all industries.

Table 1 - Crises observations

Country	Year	N Industry (Lab Prod)	N Industry (TFP)	N Firms
Argentina	1981	28	0	0
Argentina	1998	25	0	0
Brazil	1981	26	0	0
Chile	1982	27	25	0
Ecuador	1999	27	24	0
El Salvador	1981	25	24	0
Indonesia	1998	16	0	46
Ivory Coast	1983	15	0	0
Malaysia	1999	0	0	81
Mexico	1982	18	18	0
Mexico	1995	28	0	0
Nigeria	1981	7	0	0
Russia	1982	28	0	0
S. Korea	1998	28	28	14
South Africa	1998	28	0	0
Thailand	1997	0	0	71
Turkey	1994	28	28	0
Turkey	1999	26	26	0
Uruguay	1982	26	0	0
Venezuela	1981	0	0	0
Total		406	173	212

Most probably this will provide an overestimate of capital since the years before the crises were periods where investment was probably above its steady state level. In any case, the calculations above suggest that the impact of a percentage drop of investment on the growth rate of capital is of the order of $\frac{I_t}{K_t} \cong \delta$. Hence, unless the drop in investment is an order of magnitude greater than the drop in labor productivity, it is likely that the latter is a very good proxy for the drop in TFP.

Table 5 - Calibration Parameters

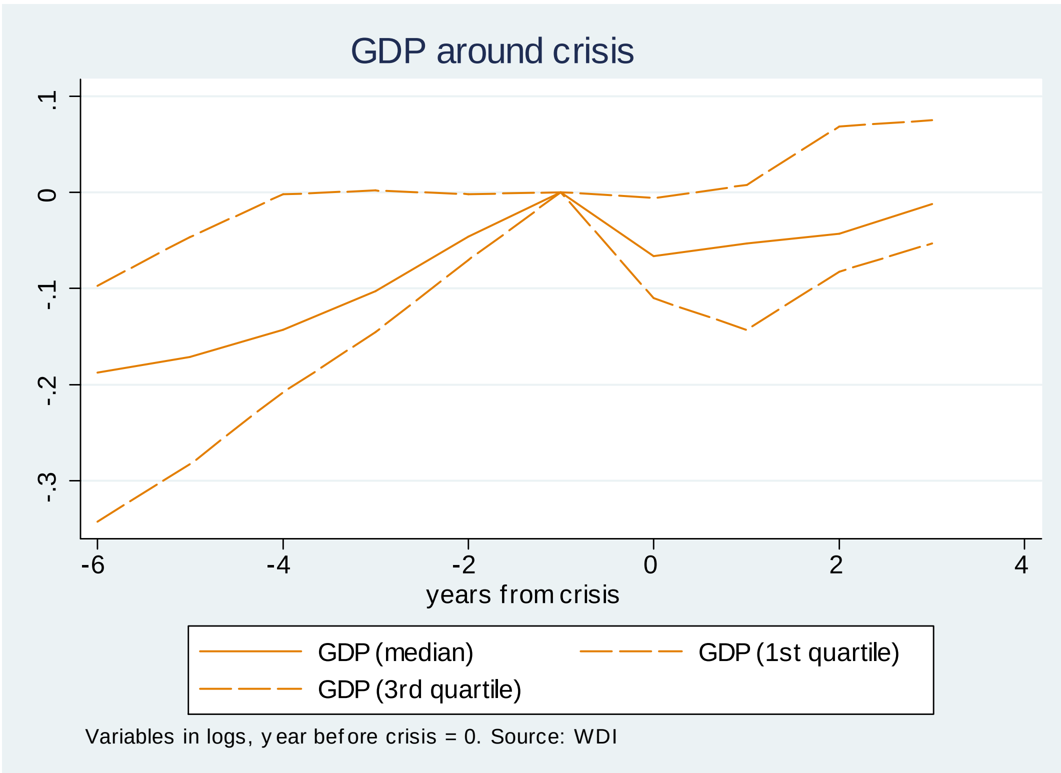

Figure 1: GDP drops around identified crises dates

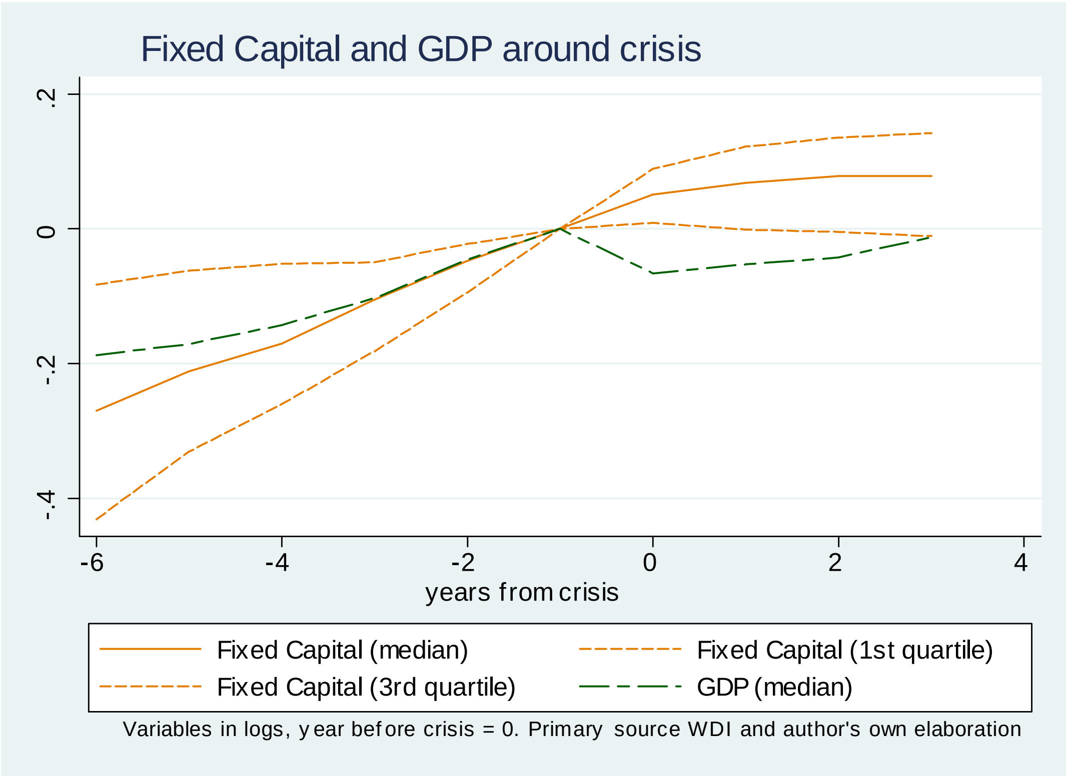

Figure 2: Capital does not drop as much as GDP around crises dates

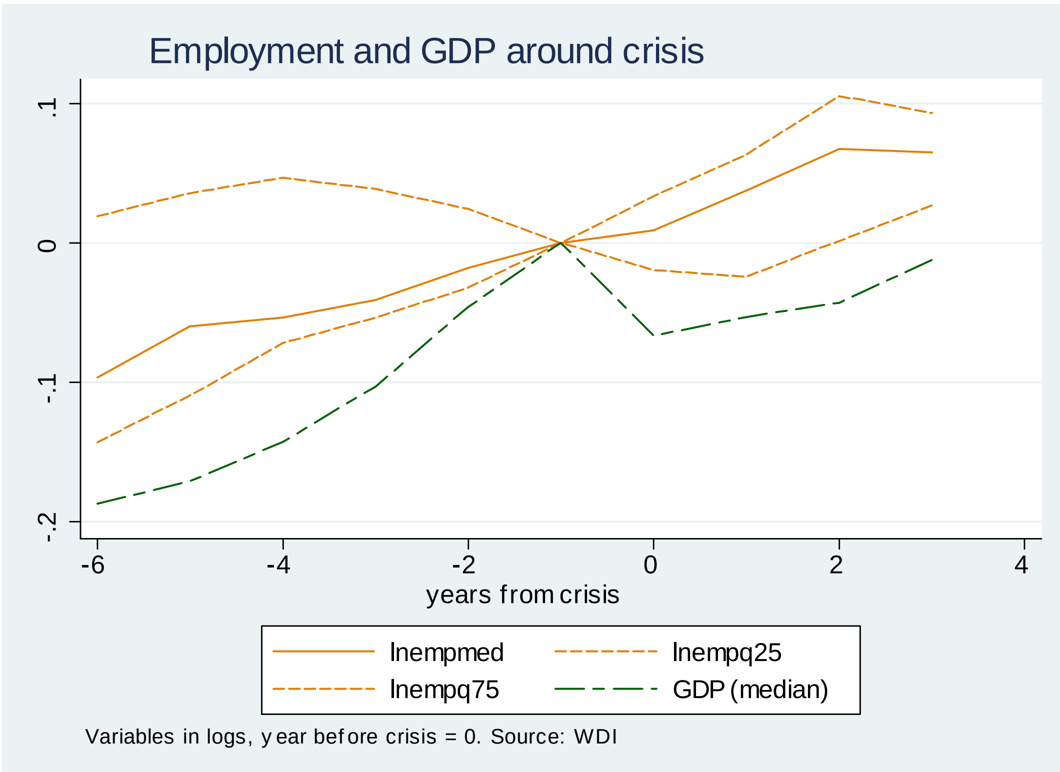

Figure 3: Employment does not drop as much as GDP around crises dates

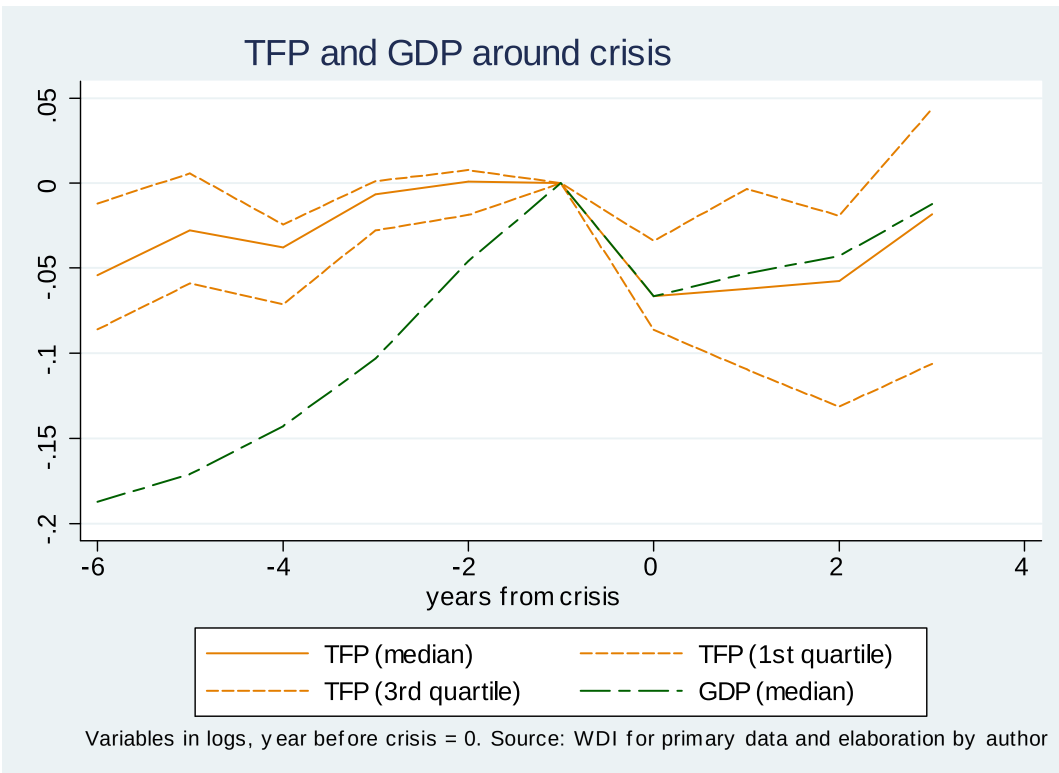

Figure 4: GDP and TFP drop in tandem around crises dates

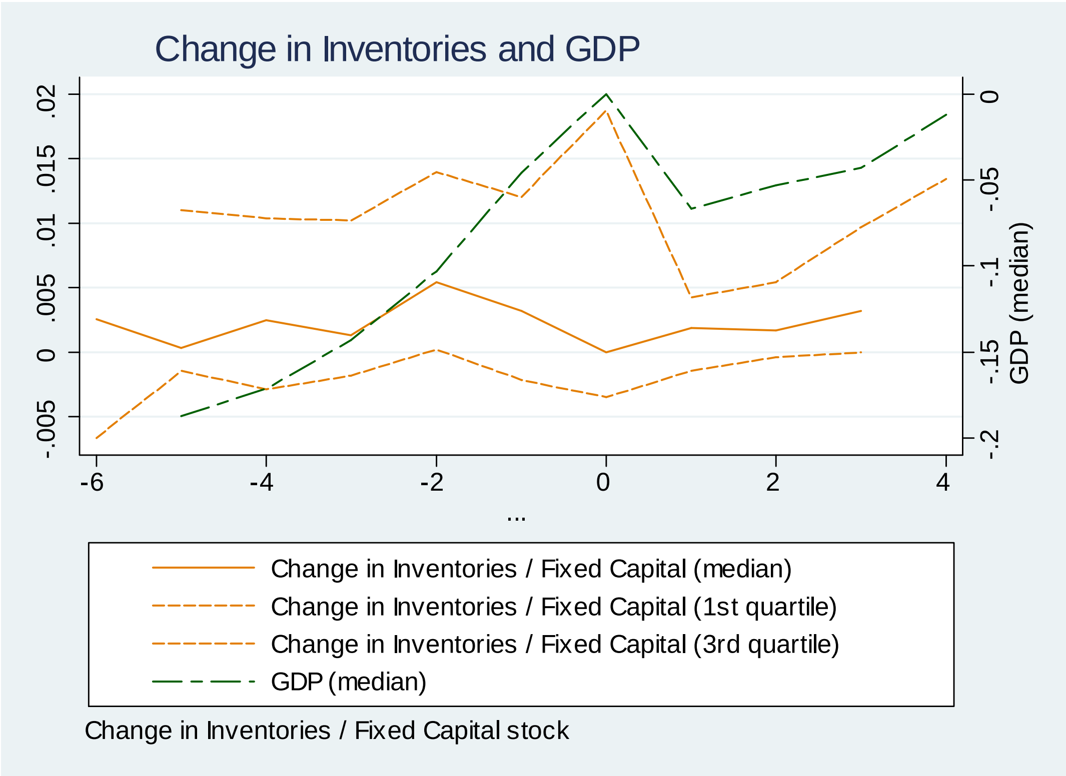

Figure 5: Inventories drop in tandem with GDP around crises dates.

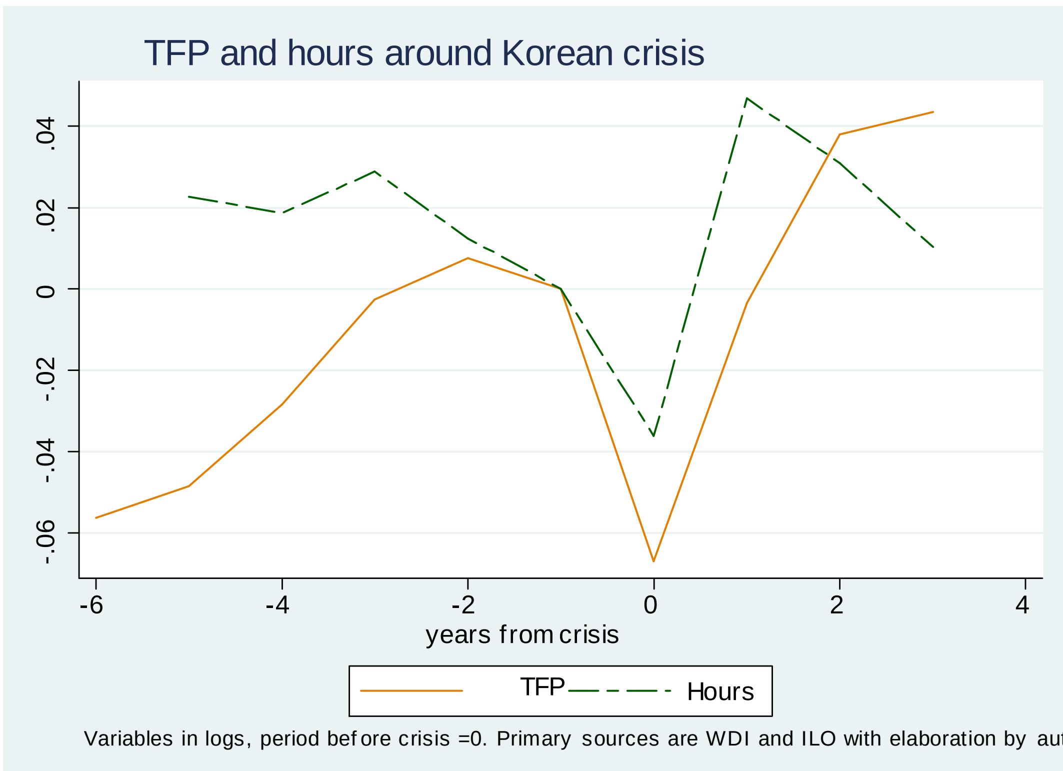

Figure 6: In South Korea, also hours worked droped

Table 2 - Correlation Matrices for industry level data

	WKINT	WKNCINT	INVINT	INVRMINT	dTFPcr
WKINT	1				
WKNCINT	0.8994	1			
INVINT	0.7437	0.7983	1		
INVRMINT	0.8166	0.8464	0.7327	1	
dTFPcr	-0.5969	-0.4454	-0.5651	-0.5862	1

	WKINT	WKNCINT	INVINT	INVRMINT	dlabprod
WKINT	1				
WKNCINT	0.8994	1			
INVINT	0.7437	0.7983	1		
INVRMINT	0.8166	0.8464	0.7327	1	
dlabprod	-0.3198	-0.376	-0.2505	-0.3994	1

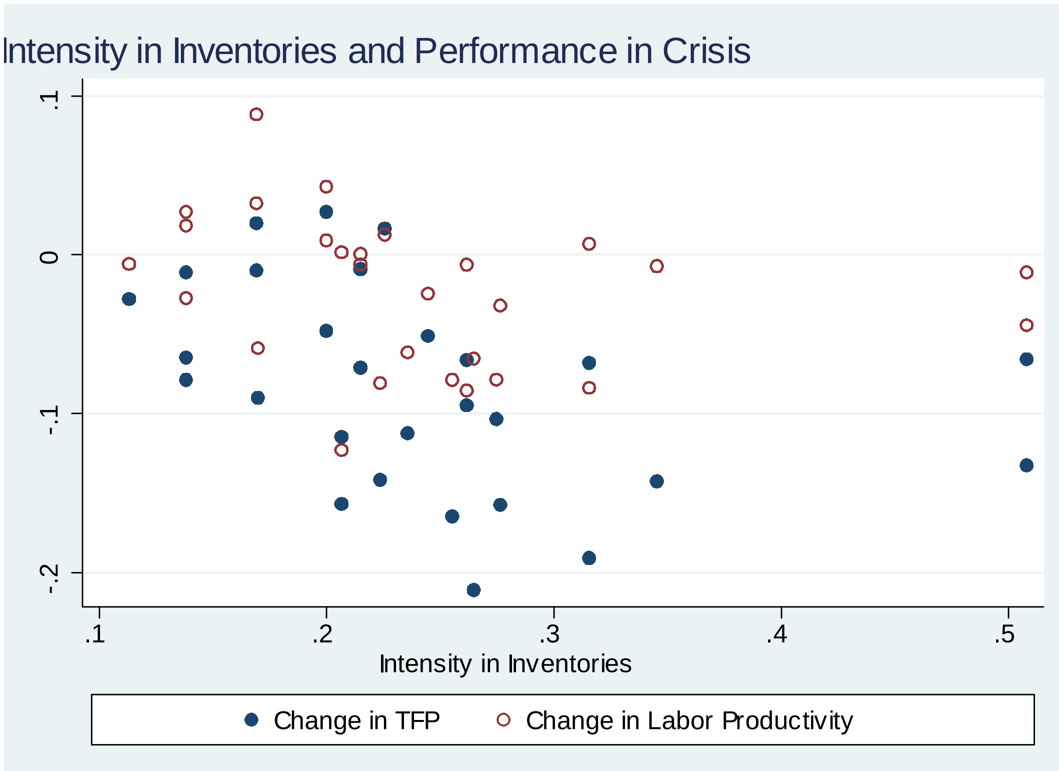

Figure 7: Sectors intensive in inventories drop more in crisis

Table 3 - Regressions of change in sales on variable capital

	Only dummies		Other controls	
Independent Variable	coefficient	p-value	coefficient	p-value
WKINTi	-0.031	-0.840	-0.081	0.040
WKNCINTi	-0.084	0.015	-0.064	0.029
INVINTi	-0.025	0.435	-0.015	0.623
INVRMINTi	-0.049	0.003	-0.024	0.301

Note: Dummies include country and industry

Other controls include number of employees and labor intensity

Standard errors clustered by industry

Table 4 - Interaction term

	Only dummies		Other controls	
Independent Variable	coefficient	p-value	coefficient	p-value
WKINTi*MARKUP(high)	0.030	0.763	0.033	0.584
WKNCINTi*MARKUP(high)	0.083	0.029	0.132	0.001
INVINTi*MARKUP(high)	0.143	0.000	0.107	0.000
INVRMINTi*MARKUP(high)	0.029	0.237	0.052	0.129

Note: Dummies include country and industry

Other controls include number of employees and labor intensity

Standard errors clustered by industry

Parameter	Value	Target/Source
σ	2	
φ	0.9971	60 years half life
β	0.9901	R^{-1}
ψ	$\frac{1}{2}$	Andolfatto (1996) [24]
χ	1.98	Workday $= \frac{1}{3}$ (Andolfatto (1996))
M	3.2317	$\frac{g(1-h)}{w} = 20\%$
ω	1.6735	$w = 1$ in steady state (normalization)
λ	0.6	Andolfatto (1996) [24]
μ	$1-\lambda$	Hosios's [25]scondition
Ξ	0.4459	$L = 57$ and $\frac{V}{Y} = 5\%$ in steady state (Andolfatto (1996))
δ_L	0.15	Andolfatto (1996) [24]
α	0.2189	Labor share $= \frac{1}{3}$
A	2	$\frac{\text{Output}}{\text{Value Added}} = \frac{1}{2}$
ζ	$\{2, \infty\}$	2 from Gertler et al. [9]
δ_k	0.025	
ρ	0.75	
γ_C	0.23	Kehoe and Ruhl [10]
γ_I	0.45	Kehoe and Ruhl [10]
γ_N	0.70	Kehoe and Ruhl [10]
γ_V	0.23	γ_C
θ	0.0630	$\frac{\text{Credit}}{\text{GDP}} = 50\%$

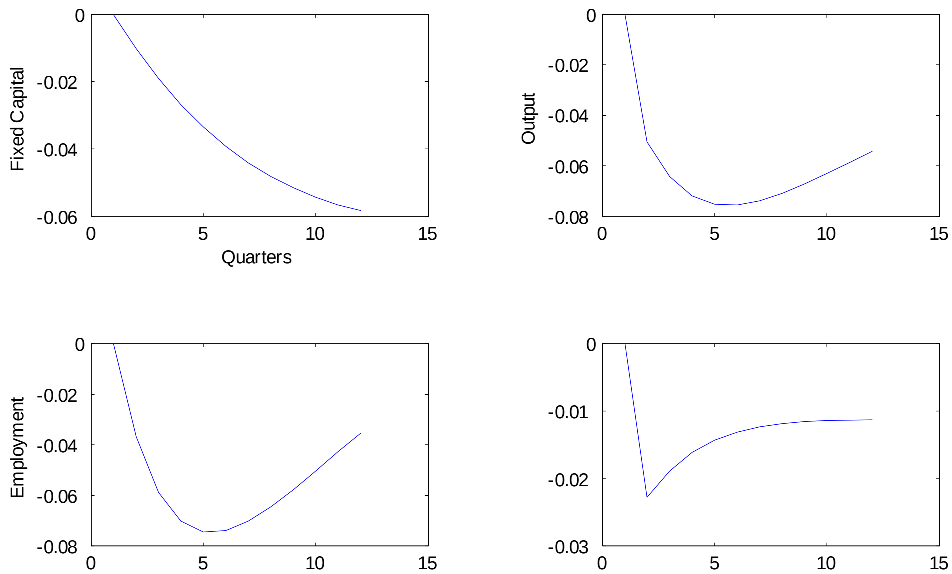

Figure 8: Impulse responses for one sector economy with adjustment cost. Responses have realistic size and direction.

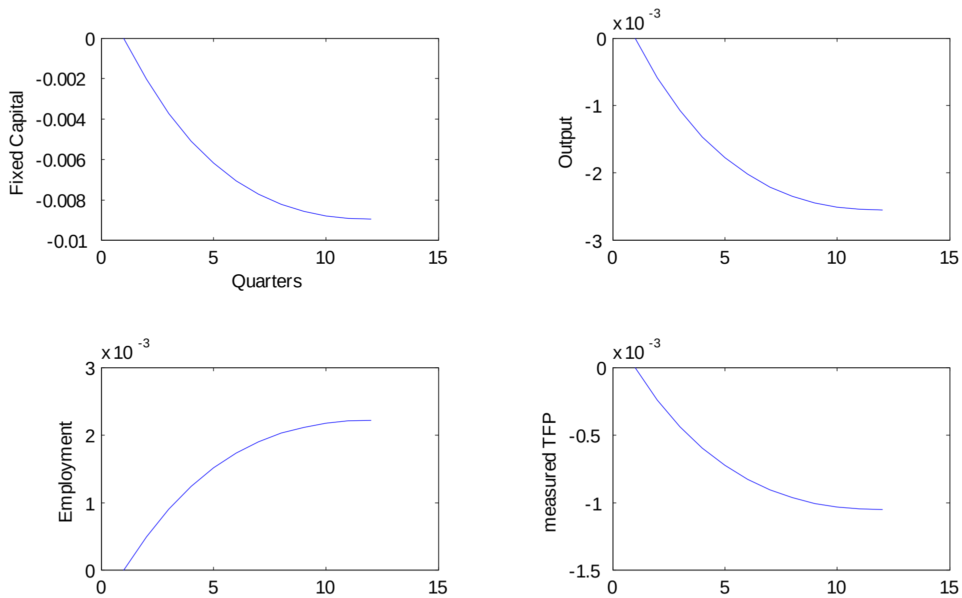

Figure 9: Model with one sector and credit frictions. The responses are an order of magnitude smaller than when credit frictions do not exist

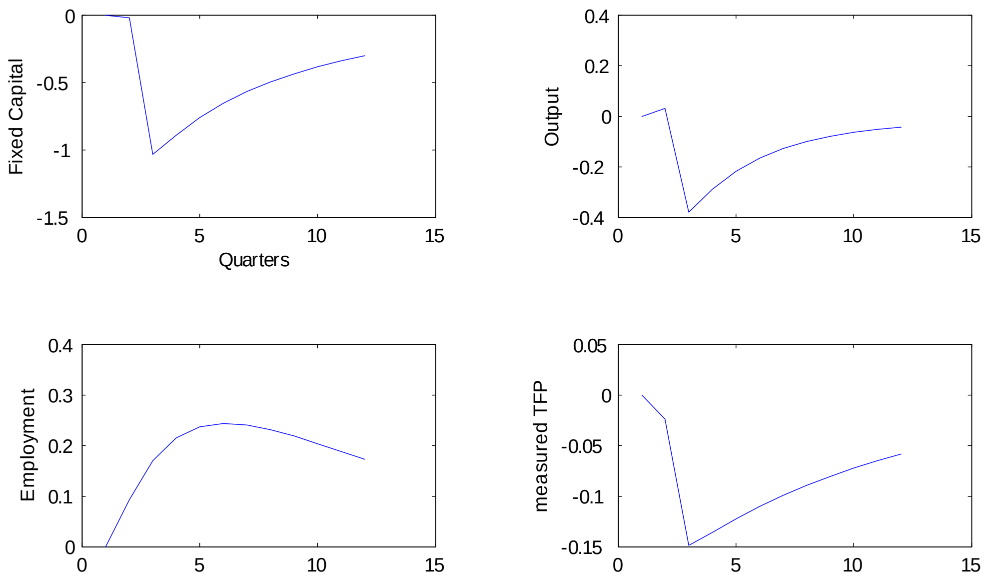

Figure 10: Two sectors, no adjustment cost or credit frictions. After a short lag, the reaction of the two sector economy is almost identical to that of the one sector.

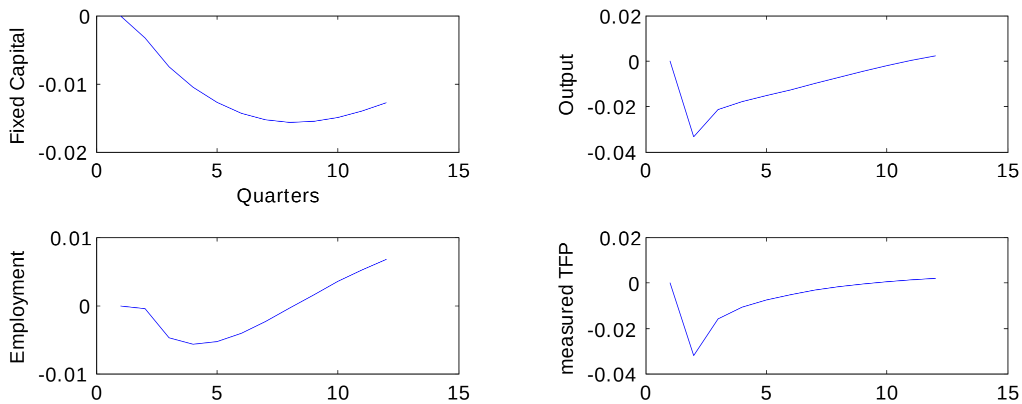

Figure 11: Two sectors and credit constraints (no adjustment costs in capital). There is pronounced v-shaped response in TFP followed by slow reversal growth. Economy exhibits oscillating pattern as output and TFP overshoot long run level in recovery

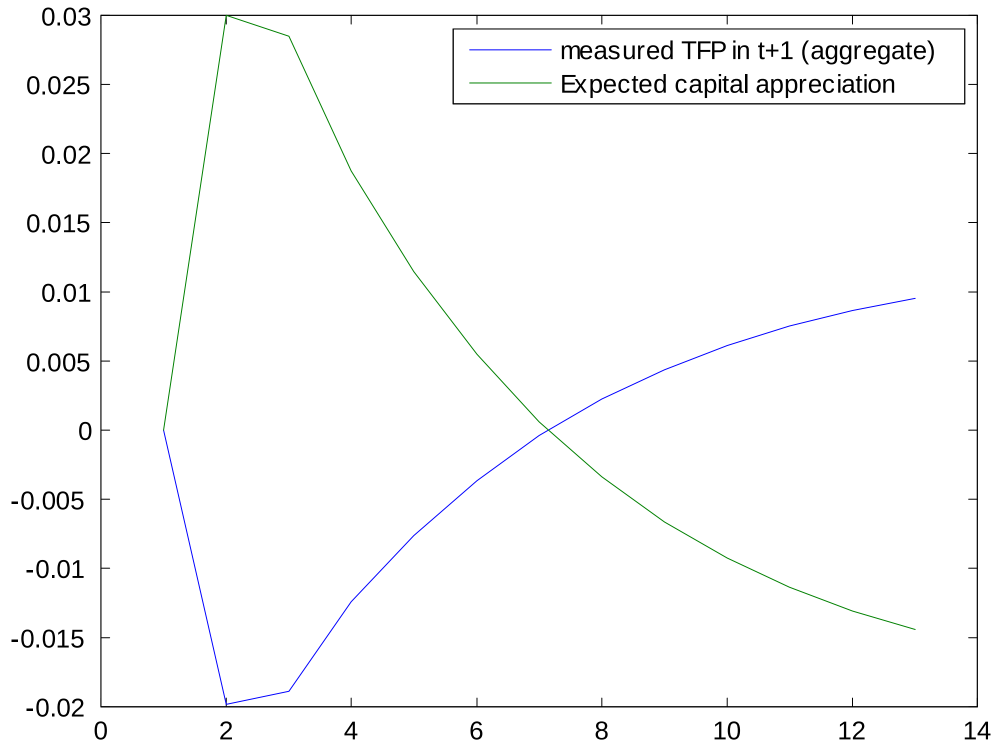

Figure 12: The main determinant of aggregate TFP in the economy with credit constraints is the expected valuation in capital. If this is high, entrepreneurs seek to transfer resources from variable capital into fixed investment, drawing TFP down.

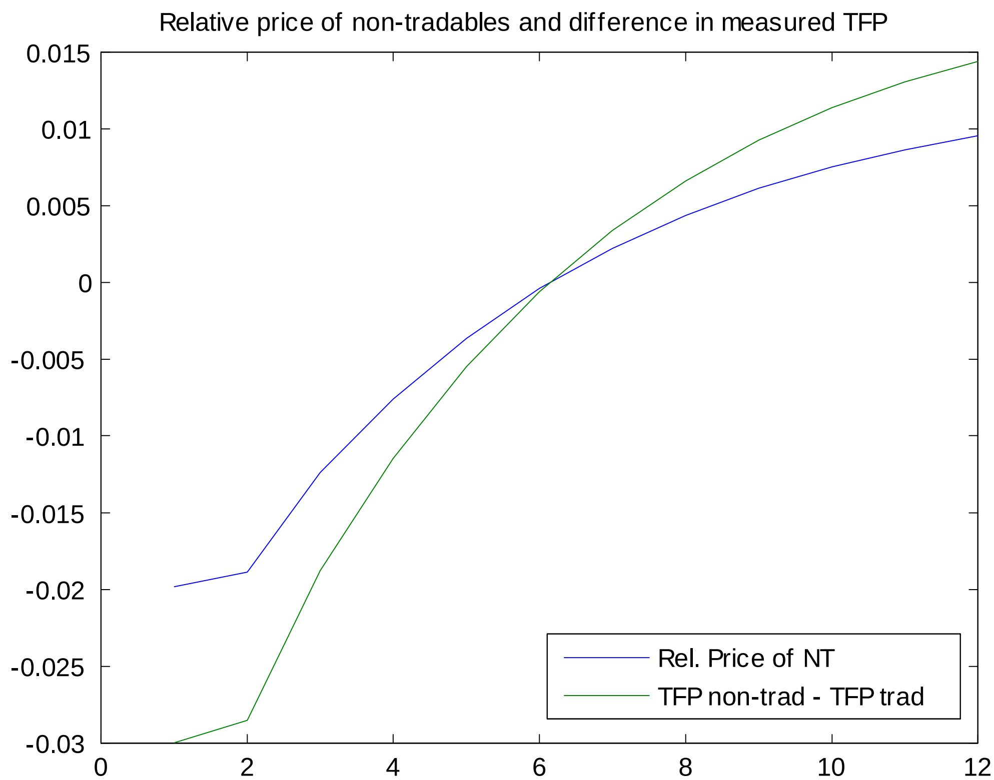

Figure 13: The difference in TFP between sectors follows the level in the relative price of the non-tradable good. TFP is larger in the tradable sector when the relative price is relatively depreciated and vice versa.