Working Paper Series

Time to Produce and Emerging Market Crises

WP 10-15R

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July 12, 2012

Abstract

The inventory/cost ratio is a measure of the time to produce and distribute goods ("time to produce") and, therefore, an important determinant of working capital demand. In the aftermath of emerging market crises, manufacturing industries with higher inventory/cost ratios experienced a larger drop in output, a drop which persisted multiple years into the recovery. This observation is shown to emerge following a persistent foreign interest rate shock in an environment where time to produce in different sectors matches inventory/cost ratios in the data. In such an environment, the interest rate shock is able to account for up to 25% of the deviation of output from its previous trend. In contrast, without time to produce, the interest rate shock generates a boom in the year of the crisis and cannot account for cross-sectoral differences. Likewise, it is impossible to generate cross-sectoral differences of the required magnitude in response to a productivity shock. These results underscore first the importance of working capital constraints as a transmission channel for financial shocks, and second, the importance of persistent interest rate shocks as a driving force of business cycles in emerging economies.

JEL classification: E22, E23, F41

Keywords: Working Capital, Time to Build, Crises, Inventories, Emerging Markets

*The views expressed in this paper are those of the author and do not necessarily reflect the position of the Federal Reserve Bank of Richmond or the Federal Reserve System. I would like to thank Nobu Kiyotaki and Markus Brunnermeier for advising me in this work. I also thank the participants in various workshops and seminars, as well as colleagues and professors at Princeton and colleagues at the Richmond Fed for helpful advice. I also thank Jonathan Tompkins for excellent research assistance. All remaining errors and omissions are my responsibility entirely.

1 Introduction

Working capital is a key link between finance and production. It consists of the (net) current assets that firms hold, many of which are tightly linked to short-term production processes. Increased cost of working capital financing is a leading explanation for the recessionary impact of capital flights in small open economies (Neumeyer and Perri (2005), Uribe and Yue (2006) among many others) and of financial shocks in closed economies (Jermann and Quadrini (2012), Quadrini and Perri (2011), Christiano et al. (2010)). In spite of its significance the quantitative business cycle literature has given little attention to the appropriate motivation, measurement, calibration and exploration of alternative implications of the working capital channel. This has considerably diminished its appeal (see Chari et al. (2005) for a critique). This paper aims to be a first step in filling this gap.

The starting point is to acknowledge that, at a minimum, working capital costs of production are a determined by the length of time that it takes to produce and distribute goods. This time is reflected in one particular item in working capital: the sum of raw material, work-in-process and finished goods inventories. A natural measure of this length of time is the steady-state inventory/cost ratios. With this measurement, students of financial crises can interpret patterns in the data and add discipline to quantitative models.

The paper applies this idea to emerging market crises, an arena where working capital has been frequently invoked as a key factor (see, for example, Mendoza (n.d.) and Meza and Benjamin (2009)). Those episodes feature simultaneous capital flights and output drops, thus constituting extreme examples of Neumeyer and Perri's (2005) finding that current-account balances are pro-cyclical in emerging economies. As such, they constitute a large departure from the international economics textbook prediction that countries should import capital in bad times. These episodes are also interesting because, unlike major recessions in advanced economies, they often featured large rises in inflation and drops in real wages, thus straining explanations that rely on nominal frictions (see Calvo et al. (2006) for these facts).[1] In the opposite direction, there is no a priori reason why the working capital mechanism should be specific to emerging economies and, as such, these episodes provide a laboratory to better understand the impact of financial crises in the US and Europe.

An empirical contribution of this paper is to document a new stylized fact of emerging market crises, defined as episodes in which there is a marked coincidence of a drop in output and capital outflows: It shows that manufacturing industries with large inventory/cost ratios take relatively longer to recover from these episodes, with the difference between industries being particularly salient three to five years after the onset of the crisis.

This stylized fact can be used to discipline models of emerging market crises. Using a quantitative model with time to produce and distribute goods (time to produce, for short) calibrated to match inventory/cost ratios, I find that the cross-sectional finding is readily explained if a) the inventory/cost ratios are good measures of working capital demand, b) foreign savings stop flowing in because they

[1] This was not the case in all episodes. See for example Gertler et al. (2007) for an account of the Korean crisis that allows for inflation and nominal frictions play a key role.

are scarcer or require a higher interest rate (as in Calvo (1998) and Mendoza (n.d.)) and c) the cost of foreign capital increases persistently relative to the pre-crisis level. With or without working capital demand, the cross-sectional finding is impossible to explain if the sole shock affecting the economy is a persistent productivity shock (as in Aguiar and Gopinath (2007)). The paper is therefore a contribution to the literature attempting to identify the relative importance of interest rate shocks versus productivity shocks in driving emerging market business cycles (see Garcia-Cicco et al. (2010) and Chang and Fernandez (2012))

With the calibrated model we can revisit the role for working capital in transforming financial shocks into output drops. In an open economy, time to produce allows for a strong negative reaction to foreign interest rate shocks even without assuming any market friction. With instantaneous production, the reduction in capital inflows only has a delayed impact, as firms fail to replace the capital stock, which then slowly depreciates. Also, with time to produce, the shock generates an immediate drop in tradable production, rather than the export boom commonly found in the literature (see Kehoe and Ruhl (2008) for an example).

The quantitative model is a generalization of the Long and Plosser (1982) model for an open economy with heterogeneity in time to produce across sectors. As such, this paper is also a contribution for the literature on multi-sector growth models (Horvath (1998), Horvath (2000), Dupor (1999), Foerster et al. (2011)). Different papers in the literature take different stands on the proper calibration of the lead-lag relationship between the different sectors, which potentially has important consequences for the propagation and amplification properties of the model. The inventory/cost ratio provides a source of discipline that so far this literature has not explored.

Finally, the empirical results in the paper are contribution to the literature on inventory investment. One puzzle in that literature is that in US data inventory investment does not seem to react to changes in the federal funds interest rate unless the changes are very persistent (Maccini et al. 2004). To the extent that the episodes under analysis are associated with persistent increases in interest rates, the cross-sectional pattern in the data confirms that these increases do interact with inventory holdings in a way which is consistent with theory.

The focus on the time to produce contrasts with a more common alternative in the quantitative business cycle literature that, rather than emphasizing the opportunity cost of holding inventories, emphasizes the cost of other components of working capital, such as cash and trade credit. In contrast, I take the step back of assuming away the credit and payment frictions that motivate looking at these components and focus solely on the size of the time gap that needs to be financed. This has some important pay-offs:

i) The opportunity cost of waiting for production to be completed and distributed is proportional to the real interest rate. This is not necessarily the case for other short-term assets and liabilities included in working-capital such as account payables, since these generate interest income of their own. It is also not the case for cash, whose opportunity cost is tied to the *nominal* interest rate, and, hence, to inflation.

ii) Conceptually there is a direct relationship between steady state inventory turnover ratios and the cost of variable inputs. This is the relationship which is important for the quantitative business cycle literature that emphasizes working capital as a channel. The same is not true for cash holdings, which can be held either to facilitate day to day input purchases or to allow firms to take advantage of sporadic investment opportunities (see, for example, Kiyotaki and Moore (2008) for a model of cash-holding centering on this latter motive).

iii) Steady state inventory turnover ratios are more likely than other components of working capital to be associated with technological characteristics of the production process as opposed to highly institutional specific payment or credit practices.[2] This robustness to institutional context considerably facilitates cross-country comparisons.

The empirical findings in this paper are complementary to independent work by Tong and Wei (2009). Using data from firms in emerging markets, the authors show that a high inventory-to-sale ratio was associated with a relatively large drop in share prices in the aftermath of the latest global crisis. Their price evidence complements the quantity evidence presented here. Raddatz (2006) presents another set of related empirical findings. He finds that industries with high inventory-to-sale ratio are relatively more volatile in countries with a low level of financial development.[3] His findings emphasize the role of the financial system in providing liquidity insurance. It is also related to work by Alessandria et al. (2010), who study the implications of inventory holdings for price dynamics in the aftermath of emerging market crises. Finally, within the United States, Maccini et al. (2004) show that inventory holdings react to the interest rate as long as the shock is a large break with previous patterns, and Jones and Tuzel (2010) find a robust relationship between inventory investment and risk premia.

Time to produce provides a channel through which financial shocks can affect output, but it leaves open the determination of these shocks. This task is undertaken by Mendoza (n.d.). The author demonstrates how a business cycle model with an occasionally binding constraint on foreign debt is able to generate alternating periods of normal business cycle variations and sudden stops.[4] In itself, these frictions only imply a slow drop in output after a sudden stop, and Mendoza relies on a payment-in-advance constraint similar to Neumeyer and Perri (2005) to generate a stronger short run impact on output. On the empirical side, a similar point applies to studies by Kroszner et al. (2006) and Dell'Ariccia et al. (2007). They find that, in banking crises, industries that rely more on external finance to fund long term investment lose relatively more of their output. Their empirical results illuminate the effect of banking crises on the cost of capital, but they leave open how this exposure

[2]For a very interesting but highly context-specific example of how changes in payment arrangements amplified an emerging market crisis, see Kim and Shin's (2007) discussion of the use of bills of exchange by Chaebols in South Korea before and after the crisis.

[3]Markups vary less than inventories across firms, so that inventories/cost and inventories/sale ratios are normally closely linked.

[4]Like in this paper, the marginal cost of capital in Mendoza (n.d.) is the same for all firms. Implicitly, the balance sheet constraints in his model are the ones faced by a representative domestic financial intermediary as opposed to individual domestic productive units, as suggested by Krishnamurthy (2003).

translates into a drop in output.

Section 2 discusses in some detail the different components of working capital and the motivation for the focus on inventories. Section 3 gives empirical results for the cross-section of industries in the aftermath of emerging market crises. Section 4 uses a simple two-sector model to lay out the main qualitative implications of the empirical results to the understanding of emerging market crises. Section 5 lays down a detailed quantitative model to allow for an evaluation of the empirical strategy in section 3 as well as a quantitative assessment of the implications derived in section 4. The last section concludes.

2 Components of Working Capital, Costs and Impact on Production

I start with a discussion of the different components of working capital, the cost of holding them and how they are linked to the production process. My main purpose is to motivate the focus on inventories throughout the paper as opposed to other components of working capital, which have received more emphasis in the literature on financial propagation.

Working capital is defined as the difference between current assets and current liabilities. This is essentially the sum of 1) inventories, 2) cash and cash-like securities and 3) trade-receivables net of, 4) trade payables.

To fix the notation, suppose that, in order to produce output Y_t firms need to use dated inputs $Z_t(0)$, $Z_{t-1}(1)$, ... , $Z_{t-V}(V)$ which are purchased at spot prices $q_t(0)$, $q_{t-1}(1)$, ..., $q_{t-V}(V)$. The time subscripts $t-v$ refers to when the input is purchased and the numbers in brackets $\{1,..,V\}$ refer to the time elapsed between the use of the input and the sale of the output. Importantly, the input $Z_{t-v}(v)$ is used to produce Y_t and not, say Y_{t+1} or Y_{t-1}. This explains why $Z_t(0)$ and $Z_t(1)$ are different entities, just as are $Z_t(1)$ and $Z_{t-1}(1)$.

This formulation accommodates linear storage technology. It is sufficient to assume that the various $Z_t(v)$'s are perfect substitutes in production so that, at any period, firms can move resources to the future by reducing $Z_t(0)$ and increasing some $Z_t(v)$ with $v > 0$. To allow for depreciation, it is possible to redefine the Z_t's to be the quantity of the input available after depreciation, with the depreciation costs conflated in the prices.

1) **Inventories**

Inventories exist because of technological constraints on the timing of production and distribution of goods. Examples of such constraints are fixed costs of transportation and the need for insurance against stock-outs. There is a vast literature that examines the details of inventory dynamics given alternative motivations for inventory holdings (see for example Ramey (1989), Blinder and Maccini (1991), Ramey and West (1999), Bils and Kahn (2000), Humphreys et al. (2001), Kahn and Thomas (2007) and Iacoviello et al. (2011), Wen (n.d.) among many others).

Standard inventory accounting uses information on the cost of goods sold at each date (as opposed to its sales value). The change in end-of-period inventories is the difference between the (spot) cost of current production and the (spot) cost of the goods sold (COGS). Algebraically,

$$Inv_t = Inv_{t-1} \underbrace{+\sum_{v=0}^{V} q_t(v) Z_t(v)}_{\text{Current Production Costs}} - \underbrace{\sum_{v=0}^{V} q_{t-v}(v) Z_{t-v}(v)}_{\text{Cost of Goods Sold (COGS)}}$$

The difference between the elements in the two summations is in the dates. Whereas all the terms in the first summation are dated t, the terms in the second are dated $t-v$. Iterating backwards and applying the boundary condition $\lim_{t\to-\infty} Inv_t = 0$ (firms start out with zero inventories),

$$Inv_t = \sum_{v=1}^{V} \sum_{j=0}^{v-1} q_{t-j}(v) Z_{t-j}(v)$$

Inventories are a triangular summation over the dated inputs. In steady state:

$$Inv = \sum_{v=0}^{V} vq(v) Z(v)$$

Inputs that are used v periods in advance of sales appear in inventories v times.

The ratio of steady state inventory to cost of goods sold (COGS) is:

$$\frac{Inv}{COGS} = \sum_{v=0}^{V} v \frac{q(v) Z(v)}{\sum_{v=0}^{V} q(v) Z(v)}$$

Inventories are denominated in dollars and the cost of goods sold is denominated in dollars per unit of time. Therefore, the ratio is denominated in time – it is the number of months worth of cost held in inventories. This ratio also shares the formula for the duration of debt, with the cost paid at each period substituting for coupon payments. This is a second sense in which the steady state inventory/cost ratio has an interpretation as the average time that it takes to produce and distribute goods.

Steady state inventories are informative about the steady state opportunity cost of production in terms of foregone interest. To see this, note that, absent any payment or financial frictions, the *economic* (as opposed to accounting) cost of producing Y_t is (recall $q_t(v)$ are spot prices):

$$Economic\ Cost_t = \sum_{v=0}^{V} R_{t-v,t} q_{t-v}(v) Z_{t-v}(v),$$

where $R_{t-v,t}$ is the interest rate faced by the firm between times $t-v$ and t. The cost of working capital finance is the difference between the economic cost and the cost of purchasing the various inputs in the spot market:

$$Working\ Capital\ Cost_t = \sum_{v=0}^{V} (R_{t-v,t} - 1)\, q_{t-v}(v)\, Z_{t-v}(v)$$

In steady state:

$$\begin{aligned} Working\ Capital\ Cost &= \sum_{v=0}^{V} (R^v - 1)\, q(v)\, Z(v) \\ &\cong \sum_{v=0}^{V} v\,(R-1)\, q(v)\, Z(v) \end{aligned}$$

Where the last expression follows from the fact that, for R close to 1, $R^v - 1 \cong v\,(R-1)$. It then follows that close to steady state:

$$\frac{Working\ Capital\ Cost}{COGS} = (R-1)\,\frac{Inv}{COGS}$$

Thus, close to steady state, working capital costs are proportional to inventories. Persistent changes in the real rate of interest that do not alter the inventory/cost ratio by much will have an impact on the ratio of working capital costs to the costs of goods sold proportional to the inventory/cost ratio.[5]

Within this context, the cost of working capital is intimately linked to production at a very short time range. This is the kind of link that allows financial shocks to have an immediate impact on output.

2) **Cash and Marketable Securities**

Firms hold cash and marketable securities for a variety of reasons. These securities may facilitate day-to-day payments of variable inputs, they may serve as cushions to allow firms to insure against negative cash flow shocks (Bates et al. (2009)), they can help firms take opportunity of fleeting investment opportunities (Kiyotaki and Moore 2008), or they can help them with their tax management (Foley et al. 2007). Of those motives, the relevant business cycle literature focuses on the first, which is the payments for variable inputs.

The simplest way to think about the use of cash for payments is through a cash-in-advance model. This corresponds to the interpretation of Christiano et al. (1992) and is the subject of empirical investigation by Ramey and West (1999).

A simple form of cash in advance model is as follows:[6] Each period is subdivided in two, morning and afternoon. Firms buy a fraction ψ of their inputs in the morning, but sell their output in the afternoon. Transactions in the morning have to be paid with cash, but financial transactions and settlements only occur in the afternoon. Thus, in order to pay for "morning" inputs firms have to hold cash overnight and forego interest payments. This generates an opportunity cost associated with

[5] This will be the case per Shepard's lemma if the change in the interest rate is small and dated inputs are transformed into output through a neo-classical production function. A proof is available upon request.

[6] The exposition follows Neumeyer and Perri (2005).

production.

If, as above, firms buy $\sum_{v=0}^{V} q_t(v) Z_t(v)$ dollars of inputs within the period, they must set aside $\psi \sum_{v=0}^{V} q_t(v) Z_t(v)$ dollars of cash in the end of the previous afternoon. When doing this, they forego $(I_t - 1) \psi \sum_{v=0}^{V} q_t(v) Z_t(v)$ dollars, where I_t is the *nominal* interest rate paid on bonds.

Since the cost of holding cash depends on the nominal interest rate, it increases vastly during hyper-inflations. This has led the emerging market business cycle literature to abandon the pure cash-in-advance model of working capital in order to avoid large shifts in the business cycle properties of the model in the transitions between high- and low-inflation regimes. Instead it has favored a cash-in-advance constraint where the opportunity cost of cash is given by the *real* rate of interest. One motivation is that firms have often access to a large variety of interest yielding securities that they can use to perform much of their payments. The opportunity cost of holding these securities is not the nominal interest rate, but their liquidity premium. The maintained assumption in the literature is that this premium varies one for one with the real interest rate paid by the governments of these countries but does not depend on inflation.

Calibrating these models requires first deciding which assets can be used and are in fact used for day-to-day payment for variable inputs into production. Since cash and marketable securities can have many different uses, using all of their holdings as a measure of working capital costs may overstate the short-run link between financial or interest rate shocks and short-term production decisions.

3) **Accounts Receivables**

The third component of working capital is accounts receivables. This has not been a focus of papers in the quantitative business cycle literature, although accounts receivables do figure as part of some of the empirical tests of the working capital channel (see Barth and Ramey (2001) and Gaiotti and Secchi (2006)). Accounts receivables are generated whenever firms extend credit to their customers. Since it is extended at the sale of goods, the opportunity cost of accounts receivables is intimately linked to short-term production decisions.

It is easy to see why accounts receivables that do not pay interest should be accounted for when calculating the cost of working capital. Under such generous lending standards, waiting for an additional week to receive a payment for a good sold is exactly the same as waiting an additional week to sell that same good.

In reality, firms do charge interest on their accounts receivables and, in fact, the literature on trade credit points out that interest rates can be very high (Petersen and Rajan (1997), but see Giannetti et al. (n.d.)). Also, even if there is evidence that firms with easier access to credit extend more trade credit to other firms, (Petersen and Rajan (1997)), it is not clear how trade credit extension varies with aggregate credit conditions.

4) **Accounts Payables**

The last component of working capital is accounts payables which, contrary to the other components, enter on the liability side. Some papers in the emerging market business cycle literature have used measures of short-term liabilities held by firms as a way to calibrate working capital demand

(Mendoza (n.d.) and Meza and Benjamin (2009)).

Accounts payables are the relevant quantity to measure the impact of fluctuations of the interest rate on the cost of variable inputs if they are secured by near-term production processes (are "self-liquidating") and if alternative sources of funding for short-term assets are not sensitive to the interest rate.

As an example, suppose firms are owned by entrepreneurs with linear utility and deep pockets. The marginal value of a dollar for these entrepreneurs is given by their discount rate β. Suppose entrepreneurs can borrow short term to purchase variable inputs v periods in advance of production at a rate $R_{t,t+v} < \beta^{-1}$, so that they choose to borrow as much as they can. Their borrowing limit is a fraction θ of the value of the inputs that they purchase. Therefore, the opportunity cost of buying inputs at t for sale v periods in the future is $\tilde{R}_{t,t+v} = \theta R_{t,t+v} + (1-\theta)\,\beta^{v}$. By analogy to the calculations for the cost of holding inventories, close to steady state the working capital cost of goods sold at t is:

$$
\begin{aligned}
Working\ Capital\ Cost &= \sum_{v=0}^{V} \left(\tilde{R}^{v} - 1\right) q\,(v)\, Z\,(v) \\
&\cong \sum_{v=0}^{V} v \left(\theta\,(R-1) + (1-\theta)\left(\beta^{-1} - 1\right)\right) q\,(v)\, Z\,(v)
\end{aligned}
$$

It follows that close to steady state:

$$
\begin{aligned}
\frac{Working\ Capital\ Cost}{COGS} &= (R-1)\,\frac{\theta Inv}{COGS} + (1-\theta)\left(\beta^{-1}-1\right)\frac{Inv}{COGS} \\
&= (R-1)\,\frac{AP}{COGS} + (1-\theta)\left(\beta^{-1}-1\right)\frac{Inv}{COGS}
\end{aligned}
$$

Where AP now are account payables. Thus, fluctuations in the interest rate affect the cost of working capital to the extent that firms are exposed to it by financing this working capital with short-term liabilities.

The approach is appealing to the extent that i) the opportunity cost of internal funds held by an entrepreneur is insensitive to the cost of outside credit, ii) short-term financing is used primarily for working capital finance, and iii) outside finance for working capital is primarily funded short term. Whether these are good or bad assumptions depend on specifics about the environment in question and are unlikely to be robust for a large range of countries with widely diverse financial institutions.

2.1 Why Focus on Inventories

The review above should highlight why inventories are a good starting point to measure the working capital costs of production. It is the only component of working capital which a) is intimately linked to short production cycles, b) has an opportunity cost which is clearly proportional to the real interest rate and c) is robust to the precise institutional environment.

3 Data Analysis

During emerging market crises, sectors with high inventory/cost suffer a persistent drop in their output relative to other sectors. The data analysis in this section shows that the differences do not reflect other plausible explanations, such as alternative sources of cross-industry heterogeneity. Also, sectors with a high inventory/cost ratio take a long time to catch up with the other sectors, if they catch up at all. This suggests that the results are not a simple reflection of short-run inventory adjustment dynamics as in Alessandria et al. (2010), whereby high inventory firms reduce production temporarily in order to reduce their inventory holdings. Lastly, the results are a robust feature of emerging market crises, having occurred in the '80s and the '90s, in Latin America and in other continents, so that they do not reflect the specificities of a particular historical or geographical circumstance.

The empirical analysis centers on events where capital inflows to an emerging market drop by an unusually large amount and where there is a drop in G.D.P. either in the same year or in the following year (see Appendix A for details). The selection criteria are similar to Calvo et al. (2008) and Calvo et al. (2006), except that there is no attempt to select clearly exogenous or unpredictable events.[7] Thus, these events are not treated as natural experiments, but as interesting episodes which generate cross-correlations that merit study with a structural model. The episodes are listed in table 1, and they include most episodes identified by Calvo et al. (2006).

Figure 1 shows the average deviation from trend of different aggregate quantities across episodes. The trend is projected from data 10 years prior to the crisis. One striking fact is that the different variables deviate very persistently from their prior trend. This is consistent with the findings in Cerra and Saxena (2008), Reinhart and Rogoff (2009) and the International Monetary Fund (2009) that financial crises have persistent impacts on output. The data replicates a key finding from Calvo et al. (2008), that investment drops much more than output, implying a drop in the investment/output ratio. Another interesting fact is that manufacturing output drops strongly after the episode, even though it is mostly tradable and hence less constrained by drops in the domestic demand components. As we will see, the co-movement between total output and tradable output is hard to explain if the only important change in the economic environment is a sudden scarcity of foreign savings (see Kehoe and Ruhl (2008). Also, see Alessandria et al. (2012) for an attempt to address that same issue). We will return to these fact when comparing the different models and shock processes in section 5.

I test whether time to produce is associated with lower performance at different horizons after the crisis. For horizons spanning from the year of the crisis to 8 years afterwards, I run the following

[7] Concretely, because there is no attempt to claim exogeneity or unpredictability, there is no filter for international financial conditions. Also, for the same reason, the selection of the episodes relies on a comparison with both post- and pre-crisis data as opposed to only pre-crisis data as in their paper. Analysis of the episodes in Calvo et al. (2006) presents the same patterns, albeit with larger standard errors because of the smaller sample size.

Country	Year	Country	Year	Country	Year
Argentina	1980	Ghana	1978	Mexico	1982
Argentina	1995	Guatemala	1986	Mexico	1988
Argentina	1999	Haiti	1992	Mexico	1994
Bangladesh	1977	Honduras	1979	Nicaragua	1977
Bolivia	1980	Honduras	1985	Papua New Guinea	1976
Brazil	1980	Hong Kong	1998	Peru	1976
Brazil	1999	Indonesia	1998	Peru	1999
Chile	1982	Jamaica	1977	Philippines	1997
Colombia	1982	Jamaica	1984	South Africa	1977
Colombia	1998	Jordania	1984	South Africa	1983
Costa Rica	1981	Kenya	1976	South Korea	1998
Costa Rica	1999	Kenya	1981	Sudan	1977
Cote d'Ivoire	1980	Kenya	1992	Thailand	1997
Cote d'Ivoire	1984	Kuwait	1975	Tunisia	1981
Croatia	1999	Kuwait	1979	Turkey	1979
Dominican Republic	1977	Kuwait	1985	Turkey	1999
Dominican Republic	1981	Malawi	1979	Uruguay	1982
Dominican Republic	2002	Malawi	1985	Uruguay	2002
Ecuador	1981	Malawi	1998	Venezuela	1975
Ecuador	1988	Malaysia	1998	Venezuela	1979
Ecuador	1999	Morocco	1993	Zambia	1976
Egypt	1990	Mauritius	1979	Zambia	1991
Ethiopia	1997	Mauritius	1982		

Table 1: Crises Episodes

The episodes start in years in which the capital account balance drops by an unusually large amount and G.D.P. drops either in the same year or in the following one.

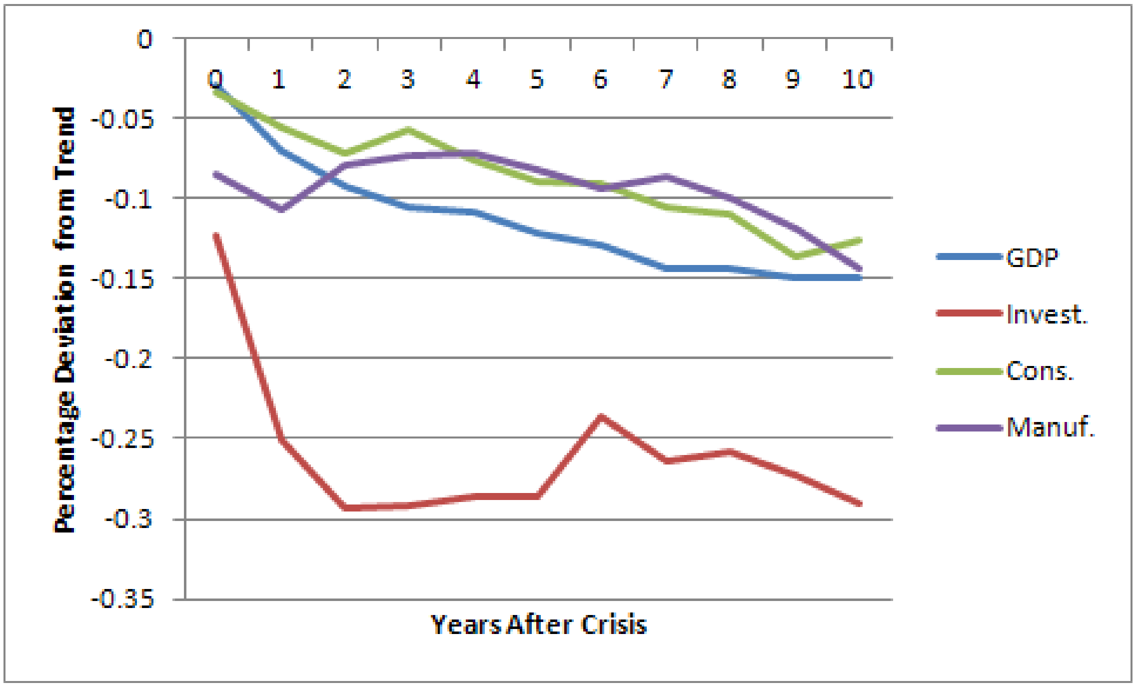

Figure 1: Aggregate Variables

Time path of variables at yearly frequency. Figures correspond to average deviation from trend calculated using average growth rate of previous 10 years.

regression:

$$y_{i,k,t^*+h} - y_{i,k,t^*-1} = \beta\tau_k + \gamma X_{i,k,t^*} + \alpha_i + \varepsilon_{ik}$$

where y_{i,k,t^*+h} is log value added in industry k, episode i, h years after the start of the event, τ_k is inventory/cost ratio for industry k and X_{i,k,t^*} is a vector of controls. I also allow for episode fixed effects α_i. The hypothesis is that $\beta < 0$, so that firms with longer production time do relatively worse.

The controls account for a large range of sources of cross-industry variation. Most important of all are the extent to which various industries are producing fixed investment goods or durable consumer goods since durable goods are notably more cyclical. I also include measures of input shares to pick up the effect of changes in the relative price of inputs following the episodes, including the share of imported inputs. A third set of controls captures trend growth for the industry in countries that were not affected by the crisis. Finally, I include variables that aim to capture the role of financial frictions, such as average firm size in each sector and the measure of financial dependence proposed by Rajan and Zingales (1998) and used by Dell'Ariccia et al. (2007) and Kroszner et al. (2006) in their empirical studies of banking crises. The data-appendix (Appendix A) includes a detailed discussion of how all of these controls are calculated.

3.1 The Inventory/Cost Ratio

Before turning to the results, I discus the measurement inventory/cost ratio in detail, since this is part of the main contribution of the paper.

Reliable measures of inventory/cost ratios are not easily available for most countries in the sample. Instead, I follow Rajan and Zingales (1998) and use data from US firms. If the inventory/cost ratios in the US reflect the underlying production technology, they should be a reasonable proxy for inventory/cost ratios in other countries. To the extent that the proxy is imperfect, the measurement error will tend to attenuate the results.

For American firms, I aggregate firm-level data from COMPUSTAT into multiple sectors. COMPUSTAT includes decades' worth of financial reports from listed firms that operate in the US. The long time series allows me to smooth business cycle fluctuations when calculating the inventory/cost ratios, obtaining something close to a steady state measure. Importantly, because COMPUSTAT is based on balance sheet data, the accounting identity between inventories and costs described in section 2 is exact, with whatever inputs that are omitted from inventories also omitted from the cost.[8]

The working assumption is that technological characteristics of listed US firms are sufficiently informative about the technological characteristics of firms in crisis countries. To validate this assumption, I check the correlation of the inventory/cost ratios calculated using COMPUSTAT against a measure of inventory-to-sales data from the Korean Financial Survey Analysis. This survey is representative of all Korean businesses and inventory-to-sales should be strongly correlated with inventory/cost as long as markups and the share of fixed inputs are not too variable across industries. The data from this survey will also be useful for robustness exercises further along.[9]

There is an unambiguous amount of correlation between the inventory/cost measures from COMPUSTAT and the inventory-to-sales data from the Korean Survey, above 0.6, (table 7). This suggests that the inventory to cost ratios do reflect underlying technological characteristics.

Table 6 has the descriptive statistics for the two variables. The average inventory/cost ratio is 2.5 months of costs held in inventories in the COMPUSTAT sample, ranging from less than a month's worth of inventories held in printing and publishing to almost four months in manufacture of electrical machinery. The average inventory/sales ratio is slightly lower in the Korean data, which is to be expected, given that sales are larger than costs. Figure 2 shows the joint distribution between the two measures.

The correlation is not perfect. This could reflect cross-country differences, but it could also reflect measurement error. Under the assumption that measurement error is classical (i.e., both measures reflect a "true" measure plus an error which is independent of the actual inventory/cost ratio), I can use the inventory sales data from Korean firms as an instrument for the inventory cost data

[8]This contrasts, for example, with the manufacturing survey data, which is only available for a much shorter time span and does not impose any accounting consistency between inventories and data. The main results are robust to using manufacturing data and are available upon request.

[9]COMPUSTAT data suggest that inventory/cost and inventory/sales are very closely correlated. The calculations are available upon request.

from COMPUSTAT, thus eliminating the measurement error and any attenuation bias that it may generate.[10] In what follows I report results both of the O.L.S. regressions and the I.V. regressions correcting for the measurement error.

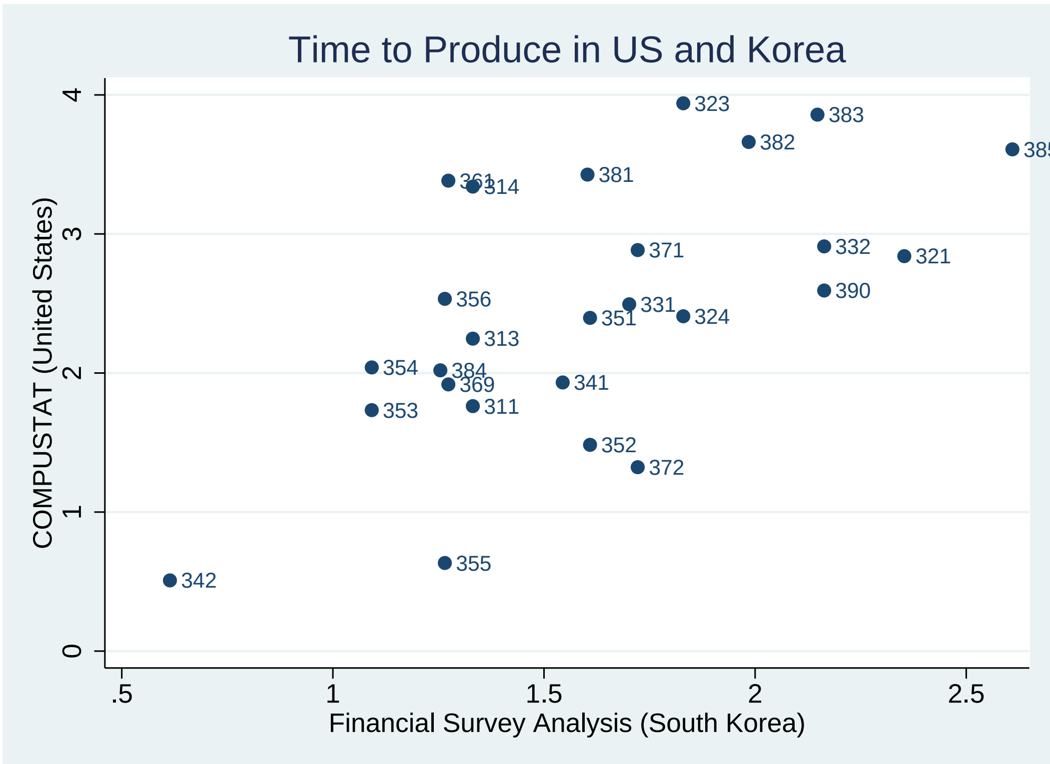

Figure 2: Inventory Intensity Measures
U.S. data are average of Inventories/Cost of Goods Sold across firms in industry, Korean data are average of Inventories/Sales across firms in industry. Industry classification is ISIC Rev. 2: 311 - Food, 313 - Beverage, 314 - Tobacco, 321 - Textiles, 322 - Apparel, 323 - Leather, 324 - Footwear, 331 - Wood Products, 332 - Furniture, 341 - Paper, 342 - Printing and Publishing, 351 - Industrial Chemicals, 352 - Other Chemicals, 353 - Refineries, 354 - Products of Petroleum and Coal, 355 - Rubber Products, 356 - Plastic Products, 361 - Pottery, China and Earthenware, 362 - Glass, 369 - Other Non-Metallic Minerals, 371 - Iron and Steel, 372 - Non-ferrous metals, 381 - Metal Products, 382 - Machinery, 383 - Electrical Machinery, 384 - Transport Equipment, 386 - Professional and Scientific, 390 - Other.

3.2 Results

Figure 3 shows the scatter plots for the change in value added for each industry averaged across episodes against τ_k, the inventory/cost ratio using COMPUSTAT data for 0, 2, 4 and 6 years after the beginning of the episode (the growth rates are with respect to the year immediately before). Three

[10]The procedure works even if a substantial part of the difference is due to cross-country variation, so long as the measurement error is not correlated with that.

aspects of the data are notable. First, there is a negative correlation between the growth rate and the inventory/cost ratios. Second, the correlation becomes more pronounced with time, peaking at around 4 years after the beginning of the episode. Last, the correlation remains negative even as the average output increases.

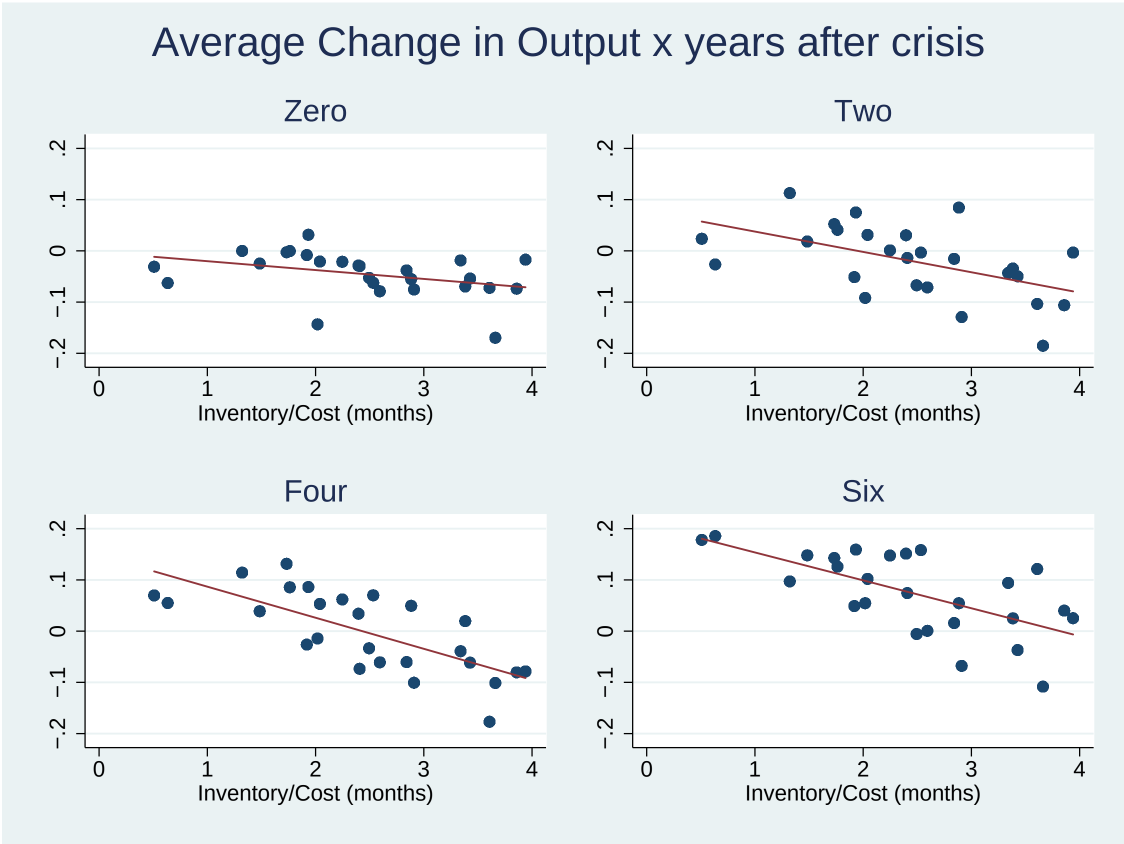

Figure 3: Correlations between Inventory intensity and Output after Crises
The horizontal axes are the Inventories/Cost of Goods Sold for each industry calculated using COMPUSTAT data. The vertical axes are the average change in value added (volume) between the year before the onset of the crisis and "t" years after that date

These raw correlations may reflect other characteristics of the data which happen to be correlated with inventory/cost ratio. Table 3 shows O.L.S. regression results and table 2 shows the I.V. regression results. The general pattern remains the same, with the coefficient under O.L.S. being statistically significant at the 5% level in years 3-5 and at the 10% level up to year 7, and the coefficient in the I.V. regressions significant at the 1% level in years 2-4, significant at the 5% level in years 5, 6, 8 and 9 and significant at the 10% level in year 1. Note that in the I.V. regression the coefficients are nearly twice as large as in the O.L.S. regressions, averaging 6.7% as compared to 3.7%.

The only other controls that are significant at any level are the investment share in the year of the crisis, average firm size in multiple years and, at a high significance level throughout, industry growth

	0 years	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years
Inventory/Cost (U.S. firms)	-0.00849	-0.0121	-0.0256	-0.0436**	-0.0435**	-0.0562**	-0.0474*	-0.0464*	-0.0427
	(0.00755)	(0.0122)	(0.0160)	(0.0190)	(0.0174)	(0.0218)	(0.0243)	(0.0274)	(0.0264)
Investment Share	-0.417**	-0.224	-0.126	-0.0755	-0.0464	-0.0155	-0.0889	0.0784	0.0302
	(0.170)	(0.141)	(0.336)	(0.385)	(0.468)	(0.421)	(0.423)	(0.462)	(0.494)
Durable Consumption Share	0.0988	-0.244	-0.403	-0.469	-0.152	-0.0400	0.0882	-0.786	-0.721
	(0.190)	(0.372)	(0.530)	(0.556)	(0.599)	(0.569)	(0.623)	(0.526)	(0.548)
Exported Share	0.187	0.0991	0.186	0.286*	0.156	0.0343	0.269	0.324	0.410
	(0.129)	(0.121)	(0.138)	(0.172)	(0.250)	(0.332)	(0.224)	(0.253)	(0.259)
Labor Share	-0.175	-0.193	-0.290	0.0534	0.0460	-0.0695	-0.705	-0.392	-0.443
	(0.237)	(0.359)	(0.379)	(0.467)	(0.455)	(0.473)	(0.663)	(0.443)	(0.452)
Capital Share	0.119	0.0853	0.0200	-0.0655	-0.231	-0.357	-0.156	-0.328	-0.246
	(0.199)	(0.204)	(0.252)	(0.355)	(0.398)	(0.396)	(0.384)	(0.557)	(0.514)
Imported Inputs Share	-0.221	-0.164	-0.194	-0.180	-0.141	-0.0992	-0.254	-0.185	-0.216
	(0.150)	(0.149)	(0.165)	(0.149)	(0.225)	(0.295)	(0.189)	(0.218)	(0.247)
External Dependence	-0.0298	-0.0293	-0.0383	-0.0521	-0.0663	-0.0359	0.00795	-0.00950	-0.00714
	(0.0196)	(0.0350)	(0.0498)	(0.0676)	(0.0745)	(0.0768)	(0.0843)	(0.0800)	(0.0752)
Size	0.0238	0.0808**	0.0892**	0.131**	0.115*	0.104	0.124	0.0837	0.0508
	(0.0244)	(0.0357)	(0.0413)	(0.0544)	(0.0650)	(0.0745)	(0.0939)	(0.103)	(0.106)
Growth in Non-Crisis Countries	0.870***	0.574**	0.593**	0.716**	0.795***	0.556***	0.542*	0.538**	0.593***
	(0.296)	(0.290)	(0.288)	(0.280)	(0.249)	(0.215)	(0.282)	(0.250)	(0.207)
Previous growth	-0.000180	0.0257	0.0438	0.0386	0.00620	0.00776	0.0154	0.0420	0.0593
	(0.0446)	(0.0494)	(0.0567)	(0.0502)	(0.0544)	(0.0589)	(0.0711)	(0.0907)	(0.105)
Observations	1,097	1,095	1,066	1,044	1,018	815	970	729	721
R-squared	0.323	0.343	0.306	0.375	0.437	0.486	0.511	0.473	0.459

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: O.L.S. Regressions: Change in Value added from $t^* - 1$ to $t^* + h$
where t^* is the starting year of a crisis event. The dependent variable is the log change in value added in the three years leading to the trough of G.D.P.. The columns refer to different horizons (h). Regressions include country fixed effects (omitted). Standard errors are robust to overlapping clusters on country and industry following (Cameron et al. 2006).

	0 years	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years
Inventory / Cost	0.00427	-0.0212*	-0.0660***	-0.0746***	-0.0899***	-0.0779**	-0.0896**	-0.0634*	-0.0908**
	(0.00985)	-0.0119	-0.0247	-0.0237	-0.0331	-0.0339	-0.0417	-0.0366	-0.0401
Investment Share	0.154	0.281	0.438	0.481	0.503	0.479	0.682	0.593	0.68
	(0.189)	-0.312	-0.391	-0.47	-0.448	-0.495	-0.485	-0.444	-0.434
Durable Consumption Share	-0.333	-0.503*	-0.553	-0.231	-0.0788	-0.176	-0.993**	-0.968**	-1.138**
	(0.226)	-0.3	-0.375	-0.407	-0.416	-0.475	-0.419	-0.386	-0.449
Exported Share	-0.0997	0.00981	0.0837	-0.0214	-0.132	0.127	0.185	0.217	0.15
	(0.0791)	-0.11	-0.185	-0.271	-0.334	-0.193	-0.249	-0.241	-0.293
Labor Share	-0.0299	-0.172	0.0557	0.0601	-0.0346	-0.605	-0.35	-0.458	-0.427
	(0.223)	-0.265	-0.363	-0.348	-0.374	-0.483	-0.322	-0.296	-0.344
Capital Share	-0.0124	-0.0777	-0.233	-0.393	-0.507	-0.286	-0.532	-0.464	-0.552
	(0.128)	-0.223	-0.34	-0.39	-0.378	-0.308	-0.461	-0.443	-0.432
Imported Inputs Share	0.0734	0.0212	0.0303	0.0585	0.0935	-0.101	-0.08	-0.0665	0.0464
	(0.0762)	-0.0635	-0.124	-0.245	-0.302	-0.127	-0.179	-0.211	-0.246
External Dependence	-0.00513	-0.00577	-0.00765	-0.0247	0.000369	0.0482	0.0458	0.042	0.0776
	(0.0195)	-0.0329	-0.0533	-0.0614	-0.0695	-0.0739	-0.0755	-0.0615	-0.0731
Size	0.0544***	0.0688*	0.112*	0.0953	0.0935	0.0881	0.0507	0.0189	0.0436
	(0.0192)	-0.0407	-0.0576	-0.0665	-0.0738	-0.0834	-0.0858	-0.0876	-0.093
Growth in Non-Crisis Countries	0.621***	0.697***	0.543*	0.698***	0.492**	0.418	0.354	0.468**	0.311
	(0.236)	-0.203	-0.305	-0.253	-0.224	-0.256	-0.227	-0.197	-0.195
Previous Growth	-0.00113	-0.0347	-0.0658*	-0.108*	-0.118*	-0.0893	-0.0684	-0.0401	-0.0381
	(0.0266)		-0.0385	-0.0588	-0.0653	-0.0628	-0.0705	-0.0848	-0.0797
Observations	1,097	1,068	1,046	1,020	972	817	731	723	723
R-squared	0.261	0.254	0.3	0.363	0.451	0.434	0.425	0.418	0.426

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Instrumental Variables Regressions: Change in Value added from $t^* - 1$ to $t^* + h$ where t^* is the starting year of a crisis event. The dependent variable is the log change in value added in the three years leading to the trough of G.D.P.. The columns refer to different horizons (h). Inventory/Cost is calculated using COMPUSTAT data and is instrumented using data from the South Korean Financial Survey Analysis. Regressions include country fixed effects (omitted). Standard errors are robust to overlapping clusters on country and industry following (Cameron et al. 2006).

in non-crisis countries.

Figure 2 provides a cleaner view of the coefficient of interest estimated for each of the time horizons, together with the 95% confidence interval. The upper panel is a graphical representation of the first line in table 3. The lower panel is the same regression coefficient for the I.V. regression. The use of instrumental variables to correct for the measurement error has a substantial impact on the result. The coefficients are almost twice as large and statistically significant at the 5% level for almost all of the years.

The lack of a strong correlation in the first few years is somewhat puzzling and could reflect slow sectoral reallocation. Alternatively, the early data might be noisy due to imprecisions in the criterion to select the crisis date.[11]

3.3 Robustness

3.3.1 Sub-samples

Crisis episodes were heavily concentrated in certain time periods and geographic regions. About half of the crises in the sample took place in the early '80s and the other half between the mid-to-late '90s. Geographically, about half of the crises were in Latin America and the rest distributed among all other continents. I assess whether the coefficient on the inventory/cost ratio is robust to splitting the sample in different ways.

The results are in figures 5 and 6. The point estimate of the coefficients is remarkably robust, as is the overall negative effect. Given that samples are half the size, it is not surprising that the statistical significance is reduced. The point estimates for the '90s do seem to mean-revert much more quickly than in the '80s.

3.3.2 A Stringent Control: Expected Cyclical Behavior

One concern is that industries are exhibiting their normally expected behavior given that aggregate output is depressed. To factor this out, I add a control to pick up whether the demand or costs of particular goods are more or less cyclical for reasons that are not well captured by the different controls. The control is calculated by running regressions of change in industry output on change in G.D.P. for periods outside of the crises episodes and using the forecast from this regression for the crisis period.

This control is very stringent, perhaps overly so. It assumes that non-crisis business cycles are qualitatively different from crisis episodes. If the results are not robust to adding the control, then all this implies is that there is no strong evidence that these large scale episodes are fundamentally

[11] One case in point is Argentina. According to the criteria, the Argentinean crisis starts in 1999, since this is the first year in which Argentinean output drops significantly and its current account surplus becomes significantly positive. But the worst of the crisis only occurs in 2001.

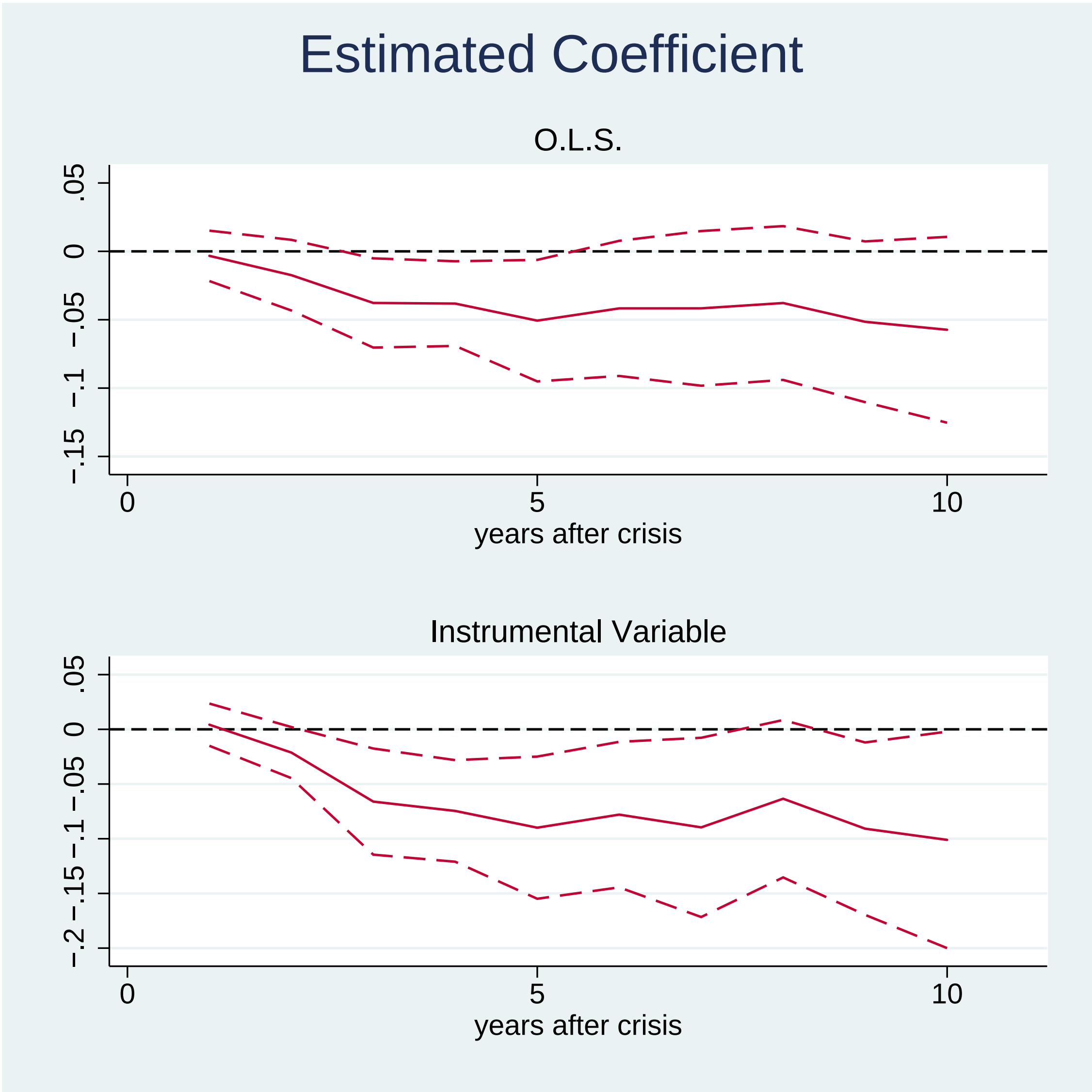

Figure 4: Estimated coefficient for different horizons.
The upper panel shows the coefficient on inventories-to-cost ratio showed in table 3, and the lower panel shows the coefficients on the I.V. regressions. The bands refer to the 95% confidence interval using two-way clustering technique following Cameron et al. (2006) with clusters by industry and by country.

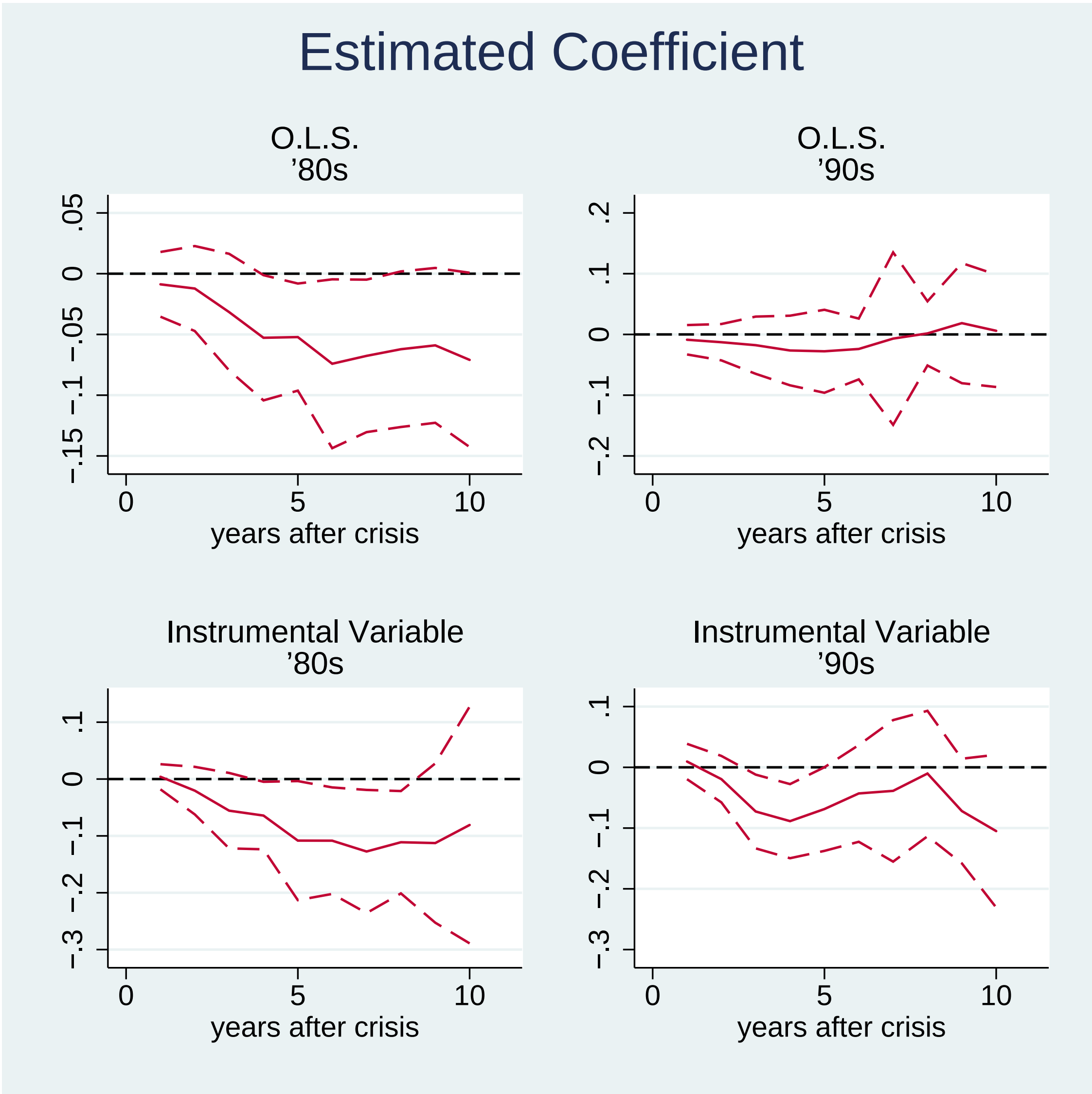

Figure 5: Estimated coefficient for different horizons and decades
The panels show the results for different decades. The upper panel shows the coefficient on inventories-to-cost ratios using COMPUSTAT data, and the lower panel shows the coefficients on the I.V. regressions using inventories-to-sales ratios from the Korean Financial Survey Analysis as an instrument for the inventories-to-cost ratio calculated using COMPUSTAT. The left panels show the estimates using crises that started in the '80s and the right panels show the estimates from crises that started in the '90s. The bands refer to 95% confidence interval using a two-way clustering technique following Cameron et al. (2006) with clusters by industry and by country.

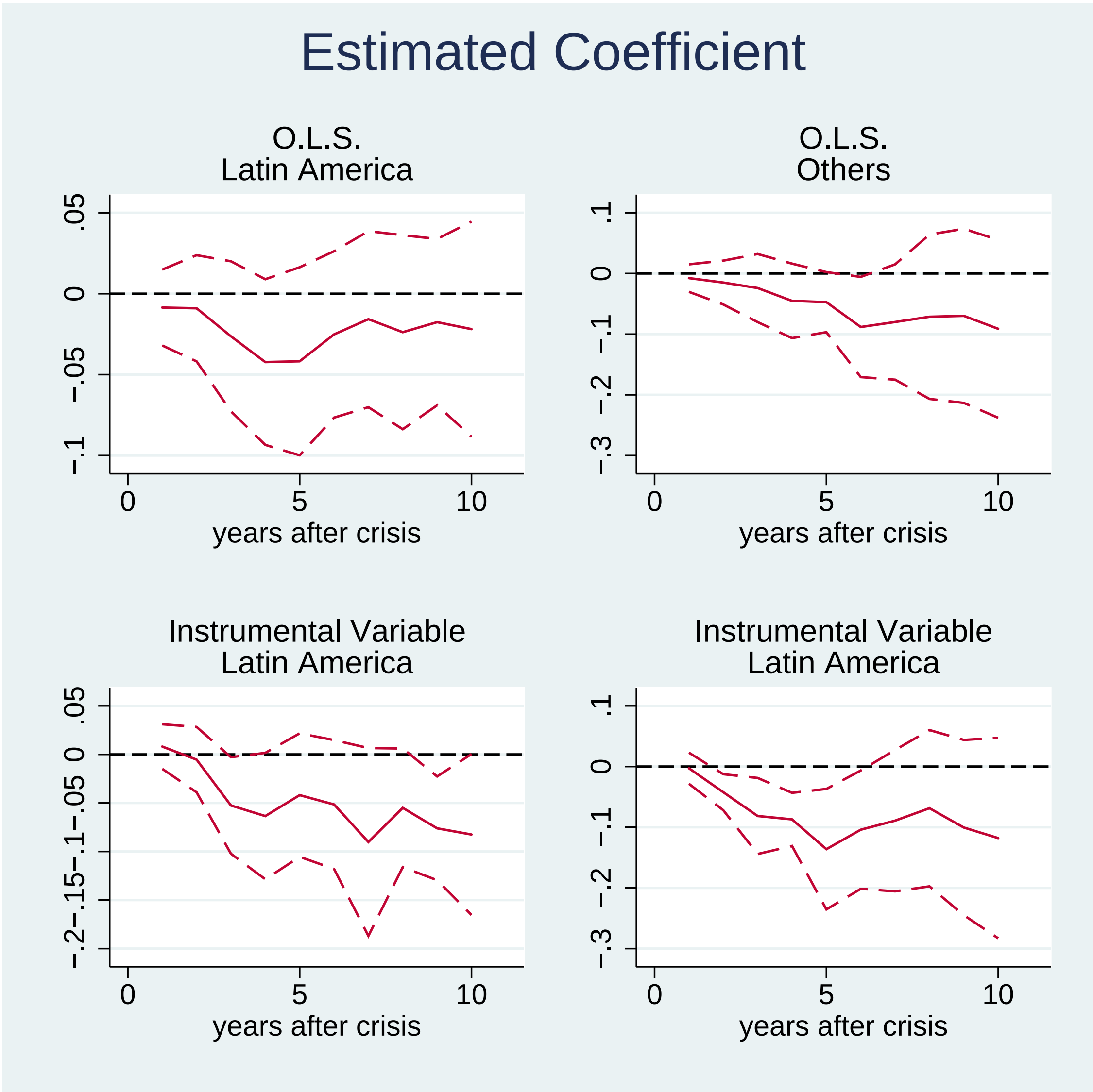

Figure 6: Estimated coefficient for different horizons and continents

The panels show the results for different continents. The upper panel shows the coefficient on inventories-to-cost ratios using COMPUSTAT data, and the lower panel shows the coefficients on the I.V. regressions using inventories-to-sales ratios from the Korean Financial Survey Analysis as an instrument for the inventories-to-cost ratio calculated using COMPUSTAT. The left panels show the estimates using crises in Latin American countries and the right panels show the estimates from crises in other continents. The bands refer to a 95% confidence interval using a two-way clustering technique following Cameron et al. (2006) with clusters by industry and by country.

different from more regular business cycles. However, to the extent that they are, they pass a very stringent test.

The result from adding this control is depicted in figure 7. Now the estimated coefficients are smaller in absolute value but still negative. Furthermore, for some of the years they cease to be significant at a 95% level, but it is still significant in one year in the O.L.S. regression and four years in the I.V. regression.

4 A Small-Scale Model

A small scale model clarifies the role of time to produce in generating cross-sectional dispersion and a drop in output in response to a shock to the foreign interest rate. The model is a variant of Mendoza (1991) and Correia et al.'s (1991) small open economy real business cycle model with two sectors instead of one and time to produce in each of the sectors. The small model allows for a direct comparison with other papers in the literature. Section 5 below uses a much more detailed quantitative model to provide a closer link to the data analysis in section 3, as well as explores the interaction of time to produce with other mechanisms of interest.

4.1 Model Setup

4.1.1 Households

There is a representative household, who is able to borrow and lend abroad at an exogenous riskless gross interest rate R_t. It can also borrow and lend to the firm. The household supplies labor, accumulates capital and consumes. The utility function of this household is time-separable with discount rate $\beta < 1$ and the period utility is

$$u\left(C_t, L_t\right) = \frac{1}{1-\sigma}\left(C_t - (1+g)^t \chi L_t^{1+\frac{1}{\psi}}\right)^{1-\sigma}$$

where C_t is consumption and L_t is labor supply and g is the growth rate of the economy.

This utility function follows Greenwood et al. (1988). One motivation is that labor supply is costly because it implies a loss in output from home production or self employment. This motivation also accounts for why the growth rate is part of the utility function (this is also necessary in order to achieve a balanced growth path). Such an interpretation is particularly suitable for developing countries, where a large fraction of the population is self-employed in an informal sector whose output is less likely to be well measured. An important implication of this utility function is that labor supply does not respond to the wealth of the household, only to wages. As a consequence, Small Open Economy business cycle models equipped with this utility function are more successful in generating realistic dynamics for the volatility of consumption and the cyclicality of the balance of trade (Correia et al. 1991).

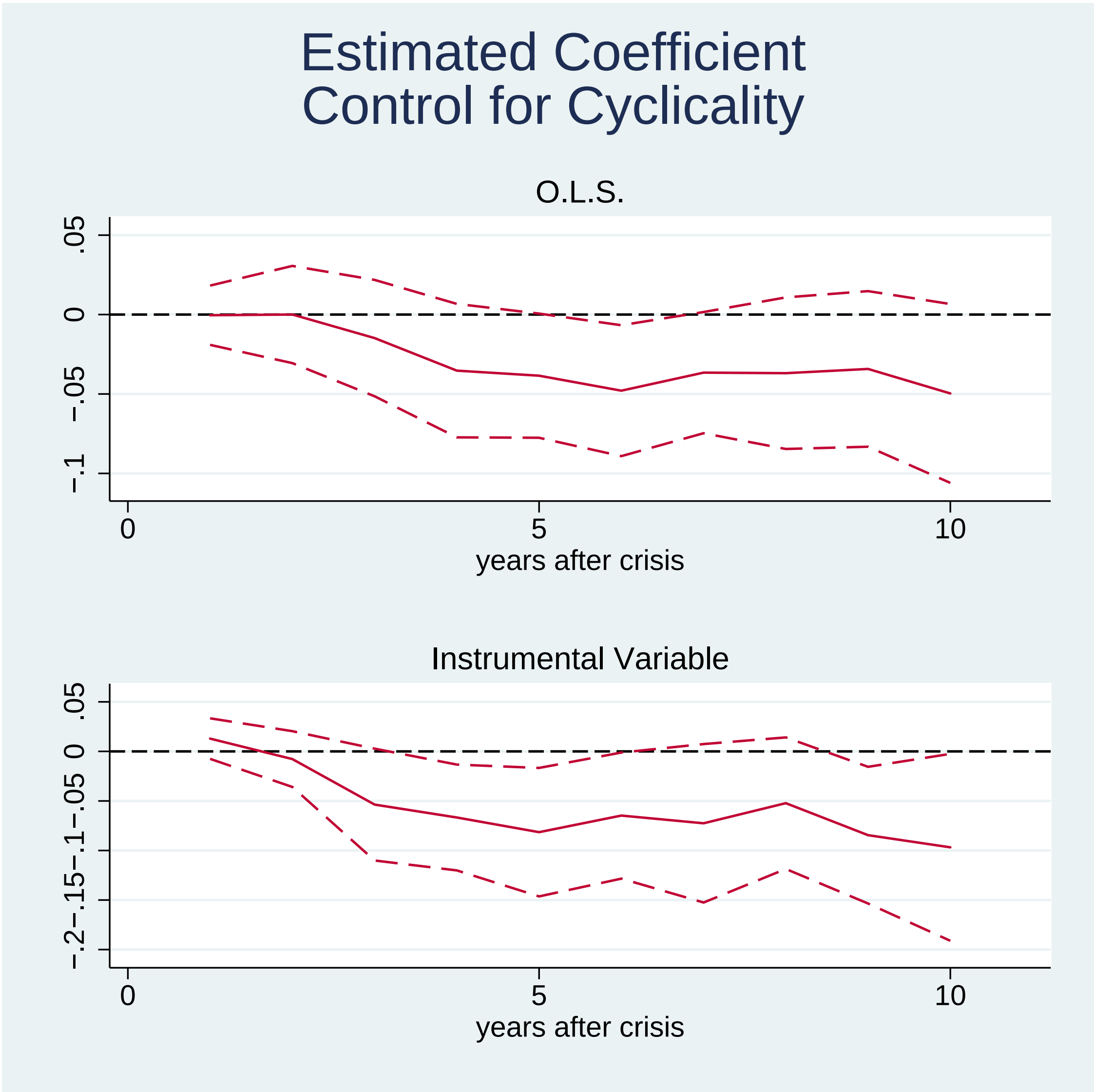

Figure 7: Estimated coefficient for different horizons, controlling for expected cyclical effect. The panels shows results controlling for the expected behavior of each industry in non-crisis periods. The upper panel shows the coefficient on the inventories-to-cost ratios using COMPUSTAT data, and the lower panel shows the coefficients on the I.V. regressions using inventories-to-sales ratios from the Korean Financial Survey Analysis as an instrument for the inventories-to-cost ratio calculated using COMPUSTAT. The bands refer to a 95% confidence interval using two-way clustering technique following (Cameron et al. 2006) with clusters by industry and by country.

Consumption is a composite of the goods produced in the two sectors and imports:

$$C_t = \Lambda_C \left(C_{1,t}^{\frac{1}{2}} C_{2,t}^{\frac{1}{2}} \right)^{1-\gamma_C^*} \left(C_{*,t} \right)^{\gamma_C^*}$$

Since this is a small open economy, the relative price of the consumption goods is set abroad. We normalize them to be equal to 1 and pick Λ so that total consumption expenditures are identical to C_t.

The household's problem is to maximize the expected discounted sum of utility functions subject to the budget constraint and the capital accumulation constraint

$$\begin{aligned} B_t^H - R_{t-1} B_{t-1}^H &= \sum_{i=1}^{2} \rho_{i,t} K_{i,t} + w_t L_t - C_t - \sum_{i=1}^{2} I_{i,t} - \frac{\kappa}{2} B_t^2 \\ K_{i,t} &= \left(1-\delta\right) K_{i,t-1} + I_{i,t} - \frac{\zeta}{2} \frac{\left(K_{i,t} - (1+g) K_{i,t-1}\right)^2}{K_{i,t-1}}, \ i \in \{1,2\}, \end{aligned}$$

where B_t^H is household financial assets including net foreign assets and firm debt, w_t is the wage rate received by the household, $\rho_{i,t}$ is the rental price of capital used in sector i and $I_{i,t}$ is the amount invested in capital of sector i. Capital is sector specific and is produced by combining old capital and investment goods. There is a quadratic adjustment cost to capital, parameterized by ζ. The parameter κ denotes a small financial friction that keeps the debt level stationary.

As with consumption, investment is a composite of goods produced in the different sectors and imports.

$$I_{i,t} = \Lambda_I \left(I_{1i,t}^{\frac{1}{2}} I_{2i,t}^{\frac{1}{2}} \right)^{1-\gamma_I^*} \left(I_{*i,t} \right)^{\gamma_I^*}$$

The price of investment is also normalized to 1 so that I_t corresponds to total expenditures in investment goods.

4.1.2 Firms

The production function of each sector is

$$Y_{i,t} = Z_{i,t}\left(0\right)^{1-\omega_i} Z_{i,t-1}\left(1\right)^{\omega_i}$$

where $Y_{i,t}$ is the production of the input i in t. $Z_{i,t}\left(v\right)$ denotes a composite of inputs acquired in period t to produce the finished good which is sold v periods ahead. $Z_{i,t}\left(v\right)$ is defined as:

$$Z_{i,t}\left(v\right) = \gamma_i \left(K_{i,t-1}\left(v\right)\right)^{\alpha_i} \left(\left(1+g\right)^t A_t L_{i,t}\left(v\right)\right)^{1-\alpha_i},$$

where $K_{i,t-1}(v)$ is capital stock, $L_{i,t}(v)$ is labor and, as before, g is the growth rate of the economy. As before, the index v implies that the input is meant for production of the output that will be available v periods in the future.

Firms maximize expected discounted profits, defined as:

$$\sum_{s=0}^{\infty} \frac{1}{R_{t,t+s}} \left[Y_{i,t} - \sum_{v=1}^{2} w_t L_{i,t}(v) - \sum_{v=1}^{2} \rho_{i,t} K_{i,t}(v) \right]$$

subject to the dynamic budget constraint:

$$B_{i,t+1}^F - R_{t-1,t} B_{i,t}^F = Y_{i,t} - \sum_{v=1}^{2} w_t L_{i,t}(v) - \sum_{v=1}^{2} \rho_{i,t} K_{i,t}(v),$$

where $B_{i,t}^F$ are financial assets held by the firm in sector i, w_t is the wage rate and $\rho_{i,t}$ is the rental rate of capital for sector i. Note that, in general, asset accumulation by firms is not equal to zero. The difference corresponds to the working capital financing need of the firm. Financial asset accumulation is also closely related to inventory accumulation, since it is determined by the difference between sales and current production costs.

4.1.3 Resource Constraints

While capital is sector specific, there is no limit in reshuffling it for production of output at different dates. This implies the following resource constraint for the capital stock of sector i:[12]

$$\sum_{v=1}^{2} K_{i,t}(v) \leq K_{i,t}.$$

Labor is perfectly mobile between sectors. This implies the following constraint:

$$\sum_{i=1}^{2} \sum_{v=1}^{2} L_{i,t}(v) \leq L_t.$$

Exports from sector i are identical to the total output from sector i minus the sum of the domestic demands for this good:

$$EXP_{i,t} = Y_{i,t} - C_{i,t} - \sum_{j=1}^{2} I_{ij,t}.$$

Total imports are the sum of all foreign produced goods demanded for different uses:

$$IMP_t = C_{*,t} + \sum_{j=1}^{2} I_{*j,t},$$

[12]The allocation procedure only determines $u_{i,t}(v) K_{i,t}(v)$ but not the individual components. This is irrelevant for any of the results, since they only depend on $u_{i,t}(v) K_{i,t}(v)$.

The prices of the foreign goods are constant over time and are normalized to be equal to 1. The current account identity is

$$B_t^* - R_{t-1} B_t^* = \sum_{i=1}^{2} EXP_{i,t} - IMP_t.$$

where B_t^* is the amount of net foreign assets that domestic households and firms hold. From Walras's law, it follows that:

$$B_t^* = B_t^H + B_t^F$$

4.1.4 Equilibrium

Given paths for the exogenous variables $\{R_t, A_t\}$, an *equilibrium* is given by quantities $\{C_t, C_{i,t}, I_{i,t}, I_{ij,t}, K_{i,t}(v), L_{i,t}(v), EXP_{i,t}, IMP_t, B_t^H, B_t^F, B_t^*\}$ and prices $\{w_t, \rho_{i,t}\}$ so that both households and firms optimize and the various resource constraints are satisfied.

4.2 Calibration

As written, the model has few parameters that need calibration, most of which are fairly standard. I follow Neumeyer and Perri's (2005) baseline calibration wherever the two models share common parameters.

We set the import shares to 20%. This is inconsequential since, as written, the model implies no movement in exchange rates and hence no interesting substitution between home and foreign goods.

The most important unconventional parameter is ω. The same inventory/cost ratios used in the empirical section provide the discipline.

To see this, note that steady state inventories are identical to the cost of paying for the early inputs that enter $Z_i(1)$. This follows from the inventory account equation:

$$Inv_{i,t} = Inv_{i,t-1} + Current\ Costs_{i,t} - COGS_{i,t},$$

where as in section 2, $Inv_{i,t}$ are inventories held in the end of period t and $COGS_{i,t}$ are the cost of goods sold. In this environment, the costs are:

$$\begin{aligned} Current\ Costs_t &= w_t (L_{i,t}(0) + L_{i,t}(1)) + \rho_{i,t} (K_{i,t}(0) + K_{i,t}(1)) \\ COGS_t &= w_t L_{i,t}(0) + w_{t-1} L_{i,t-1}(1) + \rho_{i,t} K_{i,t}(0) + \rho_{i,t-1} K_{i,t-1}(1). \end{aligned}$$

Note that all the terms in (0) cancel out so that:

$$Inventories_{i,t} = Inventories_{i,t-1} + w_t L_{i,t}(1) - w_{t-1} L_{i,t-1}(1) + \rho_{i,t} K_{i,t}(1) - \rho_{i,t-1} K_{i,t-1}(1).$$

Iterating backward and applying the boundary condition $\lim_{t\to-\infty} Inventories_{i,t} = 0$,

$$Inventories_{i,t} = w_t L_{i,t}(1) + \rho_{i,t} K_{i,t}(1).$$

The steady state inventory to costs ratio is equal to:

$$\frac{Inv_i}{COGS_i} = \frac{wL_i(1) + \rho_i K_i(1)}{wL_i(1) + wL_i(0) + \rho_i K_i(1) + \rho_i K_i(0)} = \frac{\frac{1}{R}\omega Y_i}{\left(1 - \omega + \frac{\omega}{R}\right) Y_i}$$

where the second equality follows from the first order conditions of the firm's problem. If $R \cong 1$, it follows that

$$\frac{Inv_i}{Cost_i} \cong \omega.$$

Note that we get the same result if the rental cost of capital is not accounted for in inventories and in the cost of goods sold. In that case, we have:

$$\frac{Inventories_i}{Cost_i} = \frac{wL_i(1)}{wL_i(1) + wL_i(0)} = \frac{\frac{1}{R}\omega(1-\alpha_i) Y_i}{\left(1 - \omega + \frac{\omega}{R}\right)(1-\alpha_i) Y_i} \cong \omega$$

The $1 - \alpha_i$ cancels out and we have the same equation as before. The crucial assumption is that the input shares do not vary with the time lag in which they are used. In the complete quantitative model with intermediate inputs, a similar set of assumptions will ensure that the calibration is correct if only intermediate goods are accounted for in inventories.[13]

The inventory-cost ratios calculated from the COMPUSTAT data suggest a range between 0 and 1 quarter, with the median close to half a quarter. Thus, two values of ω that are consistent with that range are $\omega_1 = 0.25$ and $\omega_2 = 0.75$. In the quantitative model below I will use the actual sector by sector calculations of the inventory to cost ratios to calibrate each different sector.

4.3 Simulations

The solid blue line in figure 4.3 shows the reaction of different variables in the model to a unit shock to the foreign interest rate that mean reverts at a rate of 78% per quarter. This coefficient of mean reversion is consistent with Neumeyer and Perri's (2005) estimates for the process of interest rate shocks. The results coincide with their findings, with consumption dropping more than output and investment even more so. With consumption and investment dropping more than output, net exports rise. The model also generates a prediction for sectoral reallocation, with the difference in output between sectors 1 and 2 increasing on impact. Recall that sector 1 is the one with a smaller share of "early" inputs so that the result is consistent with it suffering a smaller impact.

The green line marked with circles shows the same variables in the model without time to produce

[13] This is not generally the case. Work-in-process inventories include the direct labor costs of production, as do the finished goods inventories.

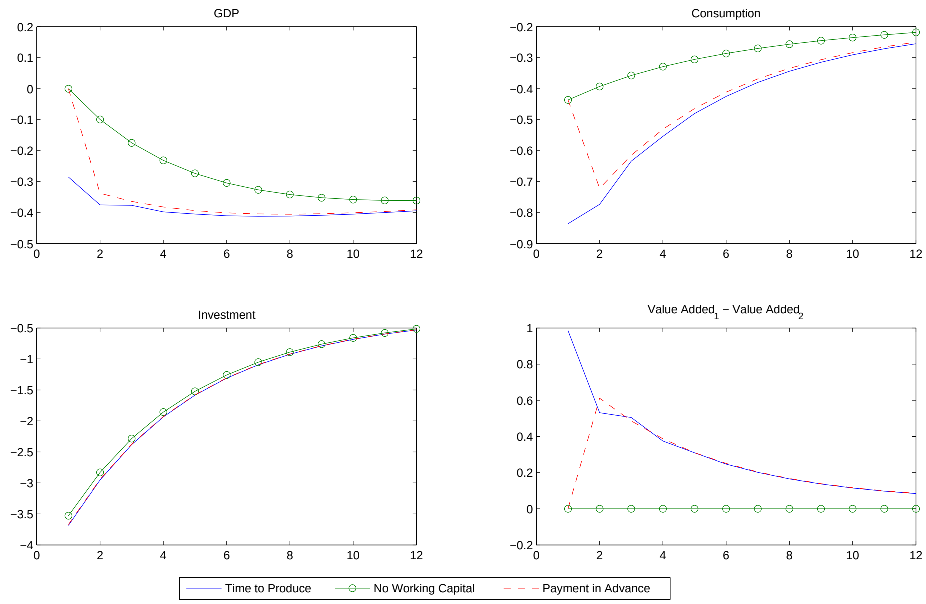

Figure 8: Impulse Response Function for R shock - Simple Model
Impulse response functions to a unit shock to the foreign interest rate with mean reversion parameter 0.78. The blue solid line ("Time to Produce") is the model proposed in the paper. The green line marked with circles ("No Working Capital") is the standard model where there is no working capital need and the dashed red line ("Payment in Advance") corresponds to the setup in Neumeyer and Perri (2005). See text for calibration. .

($\omega_1 = \omega_2 = 0$) or any other form of working capital. It makes it clear why some form of working capital financing cost of production is essential for the interest rate shock to generate an immediate drop in output. Without such a cost, output drops only slowly as fixed capital is gradually adjusted downward.

The red dashed line in figure shows how the model compares to Neumeyer and Perri's (2005) payment in advance constraint setup. Taken literally, the payment in advance setup does not imply any end-of-period inventories. Since all production takes place within the period, it cannot be disciplined by inventory holdings. Still, to facilitate the comparison, I set the share of "cash" inputs in the payment-in-advance setup to be the same as the share of early inputs in the time to produce setup.

In this setup firms only learn about the shocks after they have incurred the opportunity cost of holding "cash" inputs between periods. Hence, the effect of increased working capital costs on output is delayed. In contrast, the time-to-produce model generates a smoother initial response. The reason is that even if current sales are largely set before the shock, firms immediately reduce their production of early inputs associated to sales in the following period. Past this short-term adjustment, the two models behave essentially the same way.

Figure 9 shows the implications of a T.F.P. shock to output and sectoral reallocation in the three variants (with time to produce, without time to produce and with payment in advance constraint). There is very little difference except that the response of output is a little bit more delayed in the presence of the time to produce and that there is some initial oscillation in sectoral allocation of output. Importantly, the T.F.P. shock is unable to generate any persistent sectoral reallocation when the only source of heterogeneity is in the demand for working capital.

4.4 Main Lessons

The time-to-produce model has very similar implications to Neumeyer and Perri's (2005) cash in advance model. The finding confirms that the way the quantitative literature has been modeling working capital demand should not in and of itself have strong implications for the model dynamics.

The simple model also makes it clear that working capital is only important for the dynamics of the aggregate economy in the presence of a foreign interest rate shock. In contrast, the effects of a T.F.P. shock largely independent on whether or not there is some form of working capital. The same is true for the cross-sectional dynamics, so long as the only difference between sectors is given by the intensity of working capital demand.

The major benefit from using time to produce as opposed to Neumeyer and Perri's (2005) payment in advance constraint is that it allows to use inventories to discipline the model. This is significant because it allows for important discipline in the role of working capital. However, in order to fully exploit this benefit, it is necessary to have a more realistic model that allows for a variety of amplification and feedback mechanism. We turn to this in the next section.

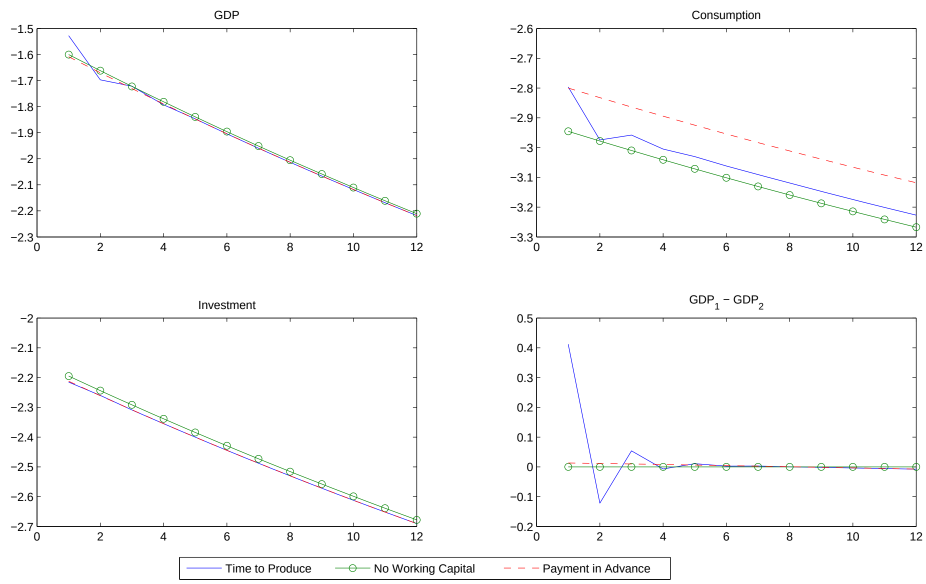

Figure 9: Impulse Response Function for T.F.P. shock - Simple Model

Impulse response functions to a unit shock to the total factor productivity with mean reversion parameter 0.78. The blue solid line ("Time to Produce") is the model proposed in the paper. The green line marked with circles ("No Working Capital") is the standard model where there is no working capital need, and the dashed red line ("Payment in Advance") corresponds to the setup in Neumeyer and Perri (2005). See text for calibration.

5 Quantitative Model

The simple model above clarified the mechanisms at play. The next step is to set up a model which is rich enough to accommodate a range of mechanisms relevant in the literature. A more complete model also allows for a meaningful effect of a range of sources of cross-sectoral heterogeneity.

The purpose is two-fold. First, the richer model, with more detailed cross-sectoral heterogeneity allows for an assessment of the empirical strategy adopted in section 2, specifically the choice of controls that make sure that cross-sectional differences reflect differences in inventory holdings and not other differences unrelated to working capital demand. Second, the model allows for a quantitative assessment of the role of time to produce in generating a sharp drop in output in response to a shock to foreign capital flows.

These additions make the model setup quite involved, so that to simplify the exposition, details are relegated to appendix B. The model is, at its core, a generalization of Long and Plosser (1982) to an open economy with time to produce calibrated to match average inventory/cost ratios. In addition to the stripped down model in section 4, the quantitative model features a number of extensions that, over time, the research on emerging market business cycles has found to be meaningful (see for example Kehoe and Ruhl (2008), Meza and Benjamin (2009), Gertler et al. (2007) among others):

- General CES utility function over goods from different sectors, as well as a general CES production function over inputs produced in the different sectors.

- Non-Tradable Production: Most production, including services and construction is non-tradable. With non-tradables the economy has fewer potential margins of adjustment since a sizeable part of output has to be used domestically. This means that non-tradables are potentially an important source of general equilibrium effects. Furthermore, non-tradables introduce an additional way to evaluate the model, which is its ability to generate co-movement between tradables and non-tradables.

- Input-Output linkages: Allowing for input-output linkages brings the model closer to a small open economy version of Long and Plosser (1982). Relative to that classic paper, one innovation is that the time lags in production that Long and Plosser (1982) assume to be identical to one quarter are in fact calibrated to match inventory holdings in different sectors. The extension allows for an assessment of the extent to which the kind of sectoral linkages that Long and Plosser (1982) argued for could account for co-movement in the presence of idiosyncratic shocks would also serve a similar role in the presence of an interest rate shock with potentially very different implications for production costs in different sectors.

- Time to build in construction. Unfinished structures are typically not accounted for as inventories, but as part of the stock of physical capital. Thus, the calibration procedure used in the paper does not properly capture all the relevant production lags in the economy. Allowing for time to build in the construction sector adds that feature.

- Household demand for durable goods: The main purpose of this addition is to allow for an additional degree of heterogeneity across manufacturing sectors, thus allowing for a more complete assessment of the empirical strategy in section 3.

- Capacity Utilization Margin: This has an important effect on the quantitative results of the model as it allows for a further margin of adjustment to shocks. In particular, as highlighted by King and Rebelo (1999), capacity utilization significantly increases the ability of small shocks to generate large business cycle fluctuations.

5.1 Calibration

5.1.1 Sectors and Shares

The model has 15 tradable sectors and 3 non-tradable sectors. The tradable sectors seek to match the manufacturing sectors in the empirical section (see appendix B for details). The three non-tradable sectors allow for differentiation between 1) construction, which has a long time to produce, and 2) services and retail, which have a short time to produce. The third non-tradable sector is residential services. Its sole purpose in the model is to absorb the residential capital built in the construction sector, thus allowing for a realistic calibration of the share of construction in manufacturing investment.

To calibrate the model, I use an average of the same input-output tables used in the data analysis section 3. The resulting input-output table has 46 sectors which I then aggregate into 18. In order to find the shares, I need to take into account that non-tradable sectors do in fact trade and that the steady state of the model features balanced trade. Appendix B discusses the assumptions and re-balancing procedures needed to accommodate them.

5.1.2 Time to Produce

The calibration process for time to produce in the manufacturing sectors follows exactly the same procedure as the one exposed in section 4 above, with the ω_i's chosen to match inventory to cost ratios. Specifically, I choose ω_i for each sector so that the inventory/cost ratio matches the numbers constructed from COMPUSTAT.[14]

The production function for the services and residential services sectors is not subject to any time to produce, so that it is simply

$$Y_{i,t} = Z_{i,t}(0).$$

[14] For sectors which encompass more than one sector in my data set, I pick the number corresponding to the one with the relatively larger value added.

Finally, the construction sector requires inputs to be accumulated over four quarters, just as in Kydland and Prescott (1982):

$$Y_{\text{Const},t} = Z_{\text{Const.},t}^{\frac{1}{4}} Z_{\text{Const.},t-1}^{\frac{1}{4}} Z_{\text{Const.},t-2}^{\frac{1}{4}} Z_{\text{Const.},t-3}^{\frac{1}{4}}. \tag{1}$$

Counter-Factual Calibration: For the sake of comparison, I also include a counter-factual calibration. I assume that all manufacturing sectors produce instantaneously, so that

$$Y_{i,t} = Z_{i,t} \ \forall i \in \{1, ..., N_T\}.$$

5.1.3 Preferences, Capital Accumulation and Capacity Utilization Cost

For the capital accumulation equations, I set the depreciation of fixed capital δ_i equal to 10% annually for all sectors except residential services. I set the depreciation rate for capital in the residential services sector to 2.3% annually. Finally, I set the depreciation of durable consumer goods δ_H to 17%. These values approximate the rate used by the Bureau of Economic Analysis to depreciate stocks of physical assets in the US economy.

I model capacity utilization costs as stemming from greater need for maintenance. Maintenance in the model requires the use of a composite good which is identical to investment, except that I exclude output from the construction sector. This is a reasonable assumption given that commercial and industrial real estate is less likely to have its depreciation depend on the speed of production. It is also quantitatively relevant, since it keeps firms from deciding to ramp up production in response to a drop in real estate prices. I calibrate the sensitivity of maintenance costs to capacity utilization, to 0.5. It is close to the estimate by Burnside and Eichenbaum (1996). I also present results when the capacity utilization margin is shut down.

I experiment with the same levels of capital adjustment cost used by Neumeyer and Perri (2005), namely 8, 25.5 and 40, with 25.5 being the benchmark, and with the same levels of elasticity labor supply, $\frac{1}{3}$, $\frac{5}{3}$, and 5, with $\frac{5}{3}$ as the benchmark.[15] I also set the curvature of the utility function σ, to 2. The household discounts the future at a rate β. I set that to $\frac{1}{R(1+g)^{\sigma}}$ in steady state, where g is the steady state growth rate of labor productivity, set to 2%. This discount rate ensures that there is no tendency for the household to accumulate or decrease assets, and choose $\bar{R}$ to match the steady state investment to output ratio.

Lastly, I set the elasticity of substitution between goods produced in different sectors to 2.

5.1.4 Shock Processes

Two exogenous variables drive the economy: total factor productivity and interest rate on foreign borrowing.

[15] Neumeyer and Perri (2005) calibrate the exponent on employment in the utility function $\nu = 1 + \frac{1}{\psi}$. The numbers above refer to ψ.

	Parameter	Value
ρ	Elasticity of substitution between home sectors	2
σ	Relative risk aversion	2
ψ	Elasticity of labor supply	$\frac{5}{3}$
β	Discount rate	0.9274% (per year)
ζ	Quadratic Adjustment Cost Parameter	25.5
δ_i	Depreciation of fixed capital	10% (per year)
$\delta_{\text{real estate}}$	Depreciation of capital in residential services sector	2.3% (per year)
δ_H	Depreciation of durables	17% (per year)
ξ	Elasticity of maintenance cost to utilization	0.5
$\bar{r}$	Steady state interest rate	12.22% (per year)
κ	Cost of holding debt	10^{-5}
χ	Coefficient on Employment in utility	2.48
g	Steady State Growth Rate	2% (per year)

Table 4: Benchmark Calibration

The interest rate shock as modeled here has two important characteristics: It is not insurable and it is not correlated with any change in the level or composition of foreign demand for domestic output. These two assumptions are consistent with a model, such as Mendoza (n.d.), Chari et al. (2005) and Kehoe and Ruhl (2008), where there is a sudden quantitative limit on the amount of resources in excess of total exports that can be transferred from abroad. Per definition, this limit cannot be insured against, and, in a decentralized setup, the imposition of this limit induces a wedge between the interest rate faced by domestic agents and that faced by foreigners. Allowing for an interest rate shock instead of a quantitative limit also accommodates models where the quantitative limit is not rigid, but the interest rate is increasing in the amount of capital inflows. A flexible enough interest rate shock could replicate the wedge between domestic and foreign interest rates induced by any such model.

I consider the impact of an interest rate shock which is part transitory and part permanent. The transitory component follows the process estimated by Neumeyer and Perri (2005) for the risk premium paid by the Argentinean government on its foreign debt to calibrate the transitory component of the interest rate shock.

The permanent component has a mean reversion parameter of 0.999. A very persistent increase in the cost of foreign borrowing is consistent with two pieces of evidence. First, after emerging market crises, credit aggregates and current account balances do not return to their pre-crisis level. Second, the investment drops much more than output, to a level which cannot be easily explained by a persistent drop in productivity (see Calvo (1998) for all of these facts).

I set the size of the foreign interest rate increase to a 10% increase in the annualized rate, consistent with the increase in the real interest rate in Argentina in 1995 and in 2001, as well as the increase in Mexico in 1995 (I calculate this using the data made available by Neumeyer and Perri (2005)), with the permanent part accounting for 1 percentage point of the initial increase.

I model the productivity shock as a permanent shift in the level of productivity, as suggested by Aguiar and Gopinath (2007). Such a permanent shift is consistent with the aggregate data discussed in the beginning of section 3, as well as with findings by the International Monetary Fund (2009) for the evolution of G.D.P. in the aftermath of financial crises in emerging economies. I calibrate the size of the productivity shock so that the economy settles at a level of G.D.P. 15% below its trend, as it appears to do on average in the data presented in figure 1 shown in section 3,

I look at the impulse response functions to individual shocks. This, rather than full-sample correlations is more likely to isolate the way the economy accommodates the extreme events analyzed in the data section. To solve the model, I log-linearize the model equations around the non-stochastic steady state and then solve for the rational expectations equilibrium. The linear approximation is necessary because of the large number of state variables.[16]

5.2 Impulse Response Functions

Figure 10 shows the response of aggregate variables to the interest rate and the productivity shock. As with the simple model, consumption responds to the interest rate shock by dropping more than output. With time to produce, the drop in output is immediate and sizeable, with a 10% shock to the interest rate generating a 1.9% drop in output relative to trend in the first quarter, whereas without time to produce the initial impact is slightly positive, becoming increasingly negative overtime, as fixed capital disperses. The intuition is the same as in the simple model: without time to produce, the interest rate shock does not have an immediate impact on production costs.

The model also generates separate responses for tradable G.D.P. Without time to produce there is an initial boom in tradable production, which grows by 8.3% on impact and does not enter negative territory until more than three years after the initial impact. The reason is that non-tradable output is constrained by domestic demand, which is depressed by the lower interest rate. The inputs freed by non-tradable production flow into tradable output, which can then be exported.

With time to produce, tradable output has close to no reaction on impact, and then slowly drops. Thus, the model is successful in generating at least some co-movement between the tradable and non-tradable sectors over the first two years after the crisis.

Finally, consumption and investment drop somewhat less in the model with time to produce than in the model without. This is because with time to produce there is less of an incentive for resources to flow from the production of consumption and investment goods (which have a high non-tradable share) to the production of exports.

The reactions to the productivity shock are largely independent of whether or not the model allows for time to produce. I investigate the response of output to a 15% permanent drop in T.F.P.. This very high number matches the average deviation from trend in the data after 9 years. Even though

[16] I solve the model using Dynare.

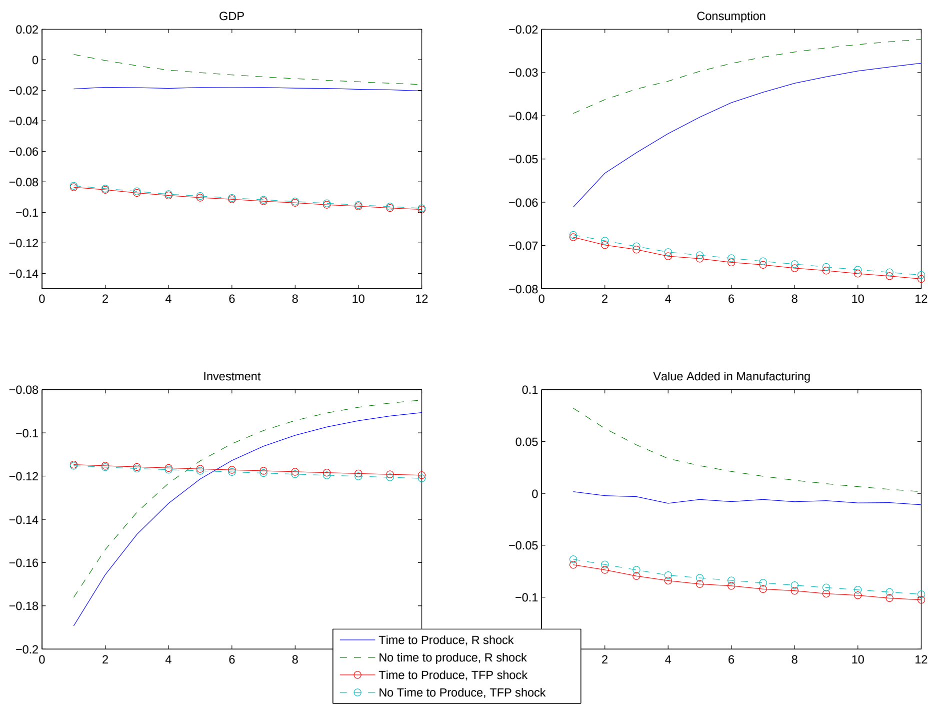

Figure 10: Impulse Response Function for Interest Rate and T.F.P. shock - Quantitative Model Impulse response functions to a 10% rise in the foreign interest rate and a 15% permanent drop in productivity. The blue solid line ("Time to Produce") is the model proposed in the paper. The green line marked with circles ("No Time to Produce") is the model without time to produce in the manufacturing sectors. See text for calibration and discussion of the underlying models..

productivity drops rapidly, output declines slowly because of the adjustment cost to capital. Because the shock is persistent, permanent income leads consumption to drop very strongly, consistent with Aguiar and Gopinath's (2007) insight. All variables co-move.

One important difference between the interest rate shock and the productivity shock is that the interest rate shock generates a drop in investment which is disproportionately large compared to output. In fact, even though the drop in G.D.P. in response to the interest rate shock is comparatively muted, the investment/output ratio drops by 9.2% between years 1 and 6 after the crisis, which is more than half of the 17% drop in the data. In contrast, the 15% drop in T.F.P. generates a drop in investment to G.D.P. ratio of only 2.7%.[17]

5.3 Cross Section: The Coefficient on Inventory/Cost Ratio

I repeat the regressions in section 3 in the model. I include as explanatory variables all the variables for which there is a model counterpart. This includes all the demand and cost shares as well as the steady state inventory/cost ratios. It excludes average firm size, external dependence, world trend and previous trend.

Figure 12 shows the coefficients on inventory/costs estimated from the model for different time horizons, with and without time to produce and with both the foreign interest rate shock and the productivity shock. The figure highlights that both time to produce and a persistent shock to the interest rate are required in order to generate sizeable coefficient of industry output on the inventory/sales ratio. The coefficient is very close to the I.V. estimates, averaging -7.6% between years 1 and 6 after the shock, compared to -6.98% in the data.

5.4 Extension: Adjustment Costs to Labor

The model with time to produce and interest rate shock fails to the extent that it implies a very large coefficient in the years immediately after the crisis, when in the actual data the sectoral differences increase much more slowly. One way to correct this is to add adjustment costs to labor (see appendix B for details). I add the same adjustment costs to labor as the ones added to capital. They are quadratic and sector specific. I also set the adjustment cost parameter in labor to be the same as in capital, 25.5.

The coefficients in figure 12 below are the ones implied by the model with adjustment costs to labor. Now there is a steady increase of the effect over time, just as in the data. Contrary to the data, there is no sign of mean reversion in the coefficient, suggesting that the simulation may overstate the degree of persistence in the interest rate shock. Again, both a persistent interest rate shock and time to produce are necessary.

[17]This particular result echoes the findings in Otsu (2007).

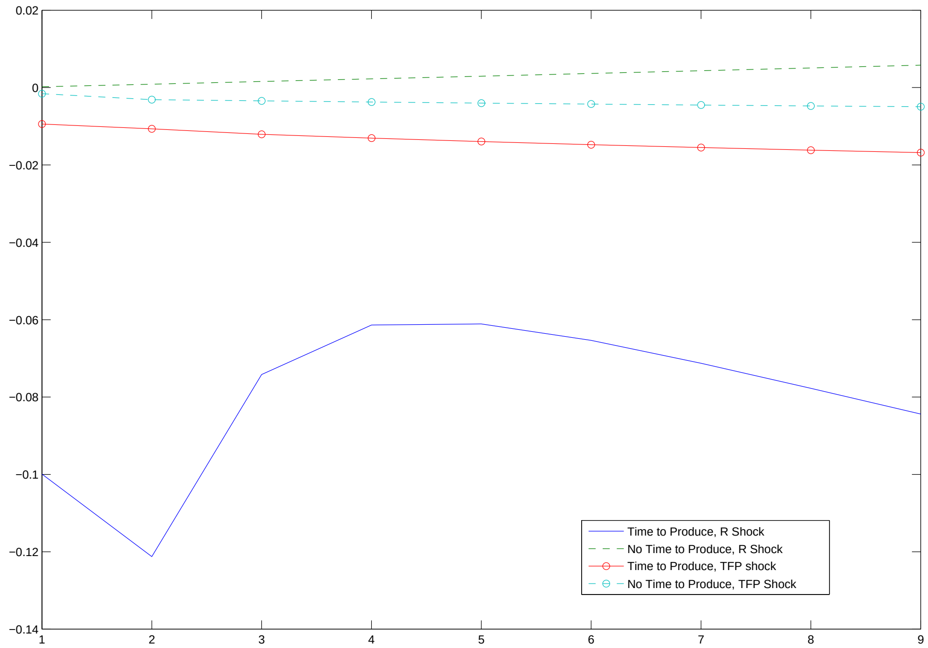

Figure 11: Coefficient of Output on Time to Produce
Output in each sector is calculated as the value added over the course of a year. Since not all crises started in the first quarter, the points correspond to an average over crises starting in each of the four quarters.

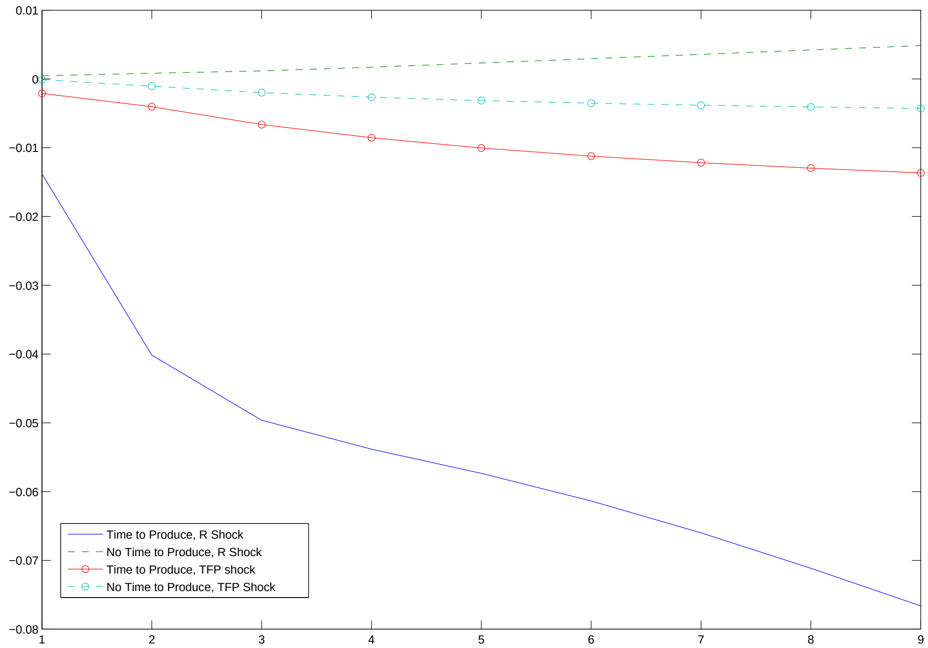

Figure 12: Coefficient of Output on Time to Produce with Labor Adjustment Costs
Output in each sector is calculated as the value added over the course of a year. Since not all crises started in the first quarter, the points correspond to an average over crises starting in each of the four quarters.

5.5 Sensitivity

The quantitative model has many constituent parts and many parameters. Table 5 deconstructs the role of these different parts and parameters in generating the aggregate and sectoral patterns in the data. The initial model is one which extends the model in section 4 by adding multiple sectors, some of which are tradables and some of which are not, inter-sectoral linkages and heterogeneity in the shares. Each subsequent row adds an additional feature to the model: time to build in construction, demand for durable consumer goods, capacity utilization margin and adjustment costs to labor. The last rows show the sensitivity of the benchmark model to different parameterizations.

The key results change very little with the degree of complexity of the model or the precise parameterizations. Under all parameterizations, a combination of time to produce and the interest rate shock is necessary to generate a large predictive effect of the inventory/cost ratio on sectoral output. Furthermore, time to produce enhances the impact of the interest rate shock on impact. Lastly, under all models and parameterizations, the T.F.P. shock generates a medium-run drop in the investment to G.D.P. which falls short of the data. In the closest entry ($\zeta = 8$) the ratio drops by only about half of what it drops in the data, even as it overshoots the output drop.

The addition to the model which has the greatest impact on the quantitative results is the capacity utilization margin. Adding capacity utilization more than doubles the impact of the interest rate shock on G.D.P. as well as the average coefficient of sectoral output on the inventory/cost ratio. In terms of long-run ratios between G.D.P. and other aggregates it changes relatively little. Adding adjustment cost to labor reduces the initial impact of the interest rate shock to 1.2% and reduces the average coefficient of output on inventory/cost ratio to about 5.5%. Otherwise results are very similar.

Finally, in terms of individual parameters, there is an interesting split between the adjustment cost to capital and the elasticity of labor supply, with the first having its major impact on the coefficient of sectoral output on the inventory/cost ratio and the latter having a large impact on the response of aggregate G.D.P. to the shock. The directions are as one would expect, with higher adjustment costs leading to a reduction in cross-sectoral differences and higher elasticity of labor supply leading to a larger drop in output.

5.6 Alternative Explanations

Here I discuss other mechanisms that do not rely on increased opportunity cost of holding capital to explain the data in section 3 and argue why they are unlikely to account for the findings.

One plausible mechanism to explain the cross-section relies on inventory adjustment dynamics as the one explored by Alessandria et al. (2010). Firms typically target some inventory-to-sales ratio. If, in response to a recessionary shock, firms desire to reduce their sales, they will also want to reduce their inventories. This requires a reduction in production above and beyond the reduction in sales. The effect will be larger if firms hold more inventories. The reason why this mechanism cannot explain the pattern in the data is that, since inventory/sales ratios are less than a quarter, firms can easily

		G.D.P. (Impact)	G.D.P. (years 1-6)	I - G.D.P. (years 1-6)	C - G.D.P. (years 1-6)	G.D.P. Trad. - G.D.P. (years 1-6)	Coef. on Inv/Cost (years 1-6)
Data		-	-10.4%	-17.0%	3.1%	2.0%	-3.79% (O.L.S), -6.98 % (I.V.)
Model 1	R, T2P	-1.2%	-2.9%	-10.3%	-0.3%	0.7%	-2.0%
	R, No T2P	-0.3%	-2.6%	-9.6%	-0.2%	1.1%	0.1%
	T.F.P., T2P	-5.7%	-7.6%	-2.7%	1.3%	0.1%	-0.9%
+ Time to Build in Const.	R, T2P	-1.1%	-3.0%	-10.3%	-0.3%	0.8%	-1.9%
	R, No T2P	-0.3%	-2.7%	-9.6%	-0.2%	1.2%	0.1%
	T.F.P., T2P	-5.7%	-7.7%	-2.7%	1.4%	0.1%	-0.9%
+Durable Consumption	R, T2P	-0.8%	-3.0%	-10.4%	-0.4%	0.7%	-2.0%
	R, No T2P	-0.1%	-2.7%	-9.7%	-0.3%	1.0%	0.1%
	T.F.P., T2P	-5.5%	-7.5%	-2.7%	1.4%	0.3%	-0.8%
+ Capacity Utilization*	R, T2P	-1.9%	-2.3%	-9.2%	-0.7%	0.8%	-7.6%
	R, No T2P	0.4%	-1.7%	-8.9%	-0.5%	1.9%	0.3%
	T.F.P., T2P	-8.4%	-10.0%	-2.4%	2.1%	-0.7%	-1.3%
Adjustment Cost to Labor	R, T2P	-1.2%	-2.2%	-9.2%	-0.7%	0.8%	-5.5%
	R, No T2P	-0.4%	-1.7%	-8.9%	-0.6%	1.7%	0.2%
	T.F.P., T2P	-10.8%	-10.2%	-2.4%	2.1%	-0.5%	-0.9%
$\zeta = 8$	R, T2P	-1.6%	-4.2%	-15.8%	0.3%	1.6%	-13.6%
	R, No T2P	0.5%	-3.6%	-15.3%	0.4%	2.8%	1.0%
	T.F.P., T2P	-8.3%	-11.2%	-8.3%	2.6%	-0.6%	-1.5%
$\zeta = 40$	R, T2P	-2.0%	-1.8%	-7.0%	-0.9%	0.6%	-6.6%
	R, No T2P	0.3%	-1.3%	-6.9%	-0.8%	1.6%	0.2%
	T.F.P., T2P	-8.4%	-9.7%	-0.2%	2.0%	-0.8%	-1.3%
$\psi = 5$	R, T2P	-3.5%	-4.0%	-10.4%	-0.2%	0.0%	-7.9%
	R, No T2P	0.3%	-3.0%	-10.1%	-0.1%	1.3%	0.2%
	T.F.P., T2P	-5.6%	-7.5%	-2.5%	2.5%	0.0%	-1.0%
$\psi = 1/3$	R, T2P	-0.7%	-1.2%	-8.7%	-1.5%	1.7%	-7.4%
	R, No T2P	0.2%	-1.0%	-8.3%	-1.3%	2.6%	0.3%
	T.F.P., T2P	-10.8%	-11.9%	-2.2%	2.0%	-1.3%	-1.6%

Table 5: Sensitity Analysis

$R, T2P$ corresponds to the results given an interest rate shock and time to produce in manufacturing, $R, noT2P$ corresponds to the results given an interest rate shock and no time to produce in manufacturing, and $T.F.P., T2P$ corresponds to the results given a total factor productivity shock and time to produce in manufacturing.

adjust their inventories to their new target level over the course of a year. However, production in inventory intensive sectors is relatively depressed several years after the crisis, by which time all these adjustment dynamics should have exhausted themselves.

A second explanation is that more cyclical sectors are naturally more likely to hold large inventories as insurance. Since inventory/cost ratios are measured using data from American firms, this is only plausible to the extent that the episodes in question were large versions of common US business cycles in terms of the cross-sectional impact. Even if this were the case, most of the uncertainty that US firms face is idiosyncratic. Insurance against aggregate shock is thus unlikely to figure as a primary reason to hold inventories.

6 Conclusion

The 2008-2009 recession had a salient financial aspect to it, leading researchers to the look for links between the financial sector and the macro-economy. The working capital channel has featured prominently as one such link. Arguably, emerging market crises were important precursors, with the difference that the role of the financial sector in mobilizing savings from foreign households to domestic investment and production played a central role. This paper shows that financial shocks have a potentially large short-run impact on output because of their effect on production costs. This helps explain how interruptions in capital inflows to a given economy can generate a drop in output even if openness to foreign trade means that production in this economy is not constrained by domestic demand.

In the specific context of emerging market crises, this paper is a contribution to the debate of whether productivity or the cost of foreign borrowing are the main drivers of business cycles in emerging economies. The results in the paper show that a productivity shock alone cannot account for the persistent pattern of cross-sectoral dispersion observed in the data, but an interest rate shock does. The quantitative model also shows that, given tightly calibrated time to produce, it is possible for such an interest rate shock to generate a sizeable immediate drop in output. In fact, the results in the paper may understate the role of time to produce given work by Pratap and Urrutia (2011) and Meza and Benjamin (2009) that shows that the interaction of working capital constraints with other frictions can lead to significant fluctuations in measured productivity and in output.

The insight that changes in the cost of capital can have a quick and sizeable impact on output is more general and applies to other setups. For example this insight might be important for the quantitative predictions of models with financial frictions. Kocherlakota (2000) argues that, since capital is a small share of output and depreciates slowly, financial frictions may not be quantitatively important, and Cordoba and Ripoll (2004) verify that this is indeed the case in a calibrated business cycle model where capital depreciates slowly. Allowing for time to produce increases the capital share and reduces average capital depreciation. It would be interesting to see how allowing for time to produce would change the results of this kind of model.

On a methodological note, this paper is an example of how cross-sectional evidence can be used to discipline macroeconomic models. If different sectors react differently to a macroeconomic event, those differences ought to provide useful information about the type of shock that is affecting the economy and the mechanism through which that shock affects the economy.

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Appendix A: Details of Data Construction

Events

The empirical analysis centers on events where capital inflows to an emerging market drop by an unusually large amount and there is a drop in G.D.P. either in the same year or in the following year.

The episodes satisfy the following criteria:

1) A large drop in capital inflows. Capital inflows are proxied on a monthly basis by the sum between the trade deficit and declines in international reserves, normalized by the linear trend of G.D.P.[18] The episodes of interest feature a pronounced change in capital flows over one year. A capital outflow event occurs when the difference between capital inflows over a 12-month period and the capital inflows in the previous 12 months is more than two standard deviations below the mean change in capital flows, with both the mean and standard deviation calculated using all data from 1975 to the present but excluding the events themselves. [19], [20]

2) Two capital outflow events that either occur in consecutive years or are separated by a single year are part of a single event.

3) There is a drop in G.D.P. either in the year when the capital outflow event starts or in the subsequent year. Including drops that only take place in the following year accommodates episodes that occur late in the year.

The criteria are similar to Calvo et al. (2008) and Calvo et al. (2006), except that there is no attempt to identify exogenous or unpredictable events that may serve as natural experiments. Rather, the methodological approach is to identify episodes which are clear cases of counter-cyclical movements in the current account, document regularities and then compare them to a model. Because there is no attempt to claim exogeneity or unpredictability, there is no filter for international financial conditions. Also, for the same reason, selection of the episodes relies on a comparison with both post and pre-crisis data as opposed to only pre crisis data as in their paper. The episodes are listed in table 1, and they include most episodes identified by Calvo et al. (2006).

Empirical Specification

I test whether time to produce is associated with lower performance at different horizons after the crisis. For horizons spanning from the year of the crisis to 8 years afterwards, I run the following regression:

$$y_{i,k,t^*+h} - y_{i,k,t^*-1} = \beta\tau_k + \gamma X_{i,k,t^*} + \alpha_i + \varepsilon_{ik}$$

[18]The proxy follows from the identity capital inflows + current account = change in reserves, together with the observation that changes in the current account are mostly due to changes in the trade balance. The methodology follows Calvo et al. (2008).

[19]Pre 1975 data were excluded as capital flows were much less volatile before the end of the Bretton Woods regime.

[20]This requires an iterative procedure where events are first calculated given overall mean and standard deviations, then the moments are recalculated excluding the event data, generating possibly new events and repeating the process.

where y_{i,k,t^*+h} is log value added in industry k, episode i, h years after the start of the event, τ_k is inventory/cost ratio for industry k and X_{i,k,t^*} is a vector of controls. I also allow for episode fixed effects α_i. The hypothesis is that $\beta < 0$, so that firms with longer production time do relatively worse.

Value added data are available in INDSTAT3, a data set compiled by UNIDO. The data originate from official sources in UN member countries. The industries are classified according to three digit ISIC Rev. 2. I do not include non-crisis data in the regressions, because the data-set includes a reasonable amount of methodological breaks in the time series that are not properly documented by UNIDO. This problem is especially severe among developing countries. By restricting the number of years of data used by each country to those around the crisis, I restrict the possibility of having these breaks contaminate the results. The use of the three digit level ISIC Rev. 2 classification allows me to have data for the early '80s.

Errors may be correlated both within episodes or within industries. To account for these correlations, the standard errors are robust to overlapping clusters at both the industry and episode level (Cameron et al. 2006).[21] For example, they allow the error term for shoes in Thailand in 1997 to be correlated both with machinery in Thailand in 1997 and shoes in Mexico in 1994. Because the standard error calculation allows for a widespread correlation between error terms, they are more conservative than usual "one-way" clustering procedures.

Inventory/Cost Ratio

For American firms, I aggregate firm level data from COMPUSTAT into multiple sectors. COMPUSTAT includes decades' worth of financial reports from listed firms that operate in the US. The long time series allows one to smooth business cycle fluctuations when calculating the inventory/cost ratios, obtaining something close to a steady state measure. Importantly, because COMPUSTAT is based on balance sheet data, the accounting identity between inventories and costs is exact.

In the benchmark regressions, the inventory/cost ratio is calculated using firm level balance sheet data from COMPUSTAT. The numerator is total inventories and the denominator is the cost of goods sold. An accounting identity ensures that the two encompass exactly the same goods, making it a precise measure. To calculate the inventory/cost ratio for a given industry, I take the median of the ratio across firms and years. Because COMPUSTAT includes observations spanning over 20 years of data, business cycle fluctuations are smoothed out. I also correct for seasonality. Most of the observations are from statements in December, so such a correction is helpful. To deal with seasonality, I first take medians over data disclosed in December and June separately. The final number is an arithmetic average of the two.

[21] I implement these in STATA using the cgmreg.ado file produced by the authors and ivreg2 for the I.V. estimates.

Controls

Sectoral reallocation can occur because of a wide range of alternative forces. These are important to the extent that they are correlated both with the inventory ratios and the change in value added in the event period. This section describes the controls. Descriptive statistics are summarized in table 6 and correlations are shown in table 7.

variable	mean	median	min	max	sd
Inventory/Cost (U.S. firms)	2.457	2.451	0.509	3.940	0.908
Inventory/Sales (Korean firms)	1.605	1.606	0.614	2.609	0.442
Investment Share	0.066	0.058	0.001	0.523	0.056
Durable Consumption Share	0.014	0.007	0.000	0.503	0.036
Exported Share	0.132	0.120	0.030	0.756	0.070
Labor Share	0.151	0.141	0.022	0.254	0.027
Capital Share	0.177	0.175	0.046	0.379	0.046
Imported Inputs Share	0.126	0.116	0.018	0.775	0.053
External Dependence	0.244	0.220	-0.450	1.140	0.330
Size	1.365	1.438	-2.057	2.144	0.371

Table 6: Descriptive Statistics

Inventory/Cost (U.S. firms) is the median ratio of inventories-to-cost across firms and years in the COMPUSTAT database using data since 1980. Inventory/Sales (Korean firms) is the average ratio of inventories-to-sales in the Financial Statement Analysis collected by the Korean government. Export, Investment and Durable Consumption represent the fraction of sectoral output that eventually finds its way to either of these final uses. Durable Consumption includes all consumption from industries whose ISIC numbers start with 33, 36 and 38 (Wood Products, Non-Metallic Minerals and Machinery and Equipment). External Dependence is the dependence on external financing as defined by Rajan and Zingales (1998). The numbers are taken from their paper. Size is the average over time of the ratio between employees and establishments for each country/industry observation calculated with data from the UNIDO database.

Demand Side

Demand for different goods reacts differently in a downturn. In particular, the more durable a good, the more pro-cyclical its demand. On the other hand, the more tradable a good, the less it should be affected by conditions that affect domestic demand.

A measure of the share of output that is ultimately destined to the production of exports, investment goods and durable consumer goods can be calculated from input-output matrices made available by OECD. The measure uses the Leontief inverse to allow for indirect effects through the supply chain. For example, this clarifies that basic metals are sold largely as investment goods.

	Inventory/Cost, U.S. firms	Inventory/Sales, Korean firms
Inventory/Cost, U.S. firms	1	
Inventory/Sales, Korean firms	0.6135	1
Investment Share	0.3584	0.2556
Durable Consumption Share	0.3977	0.4895
Exported Share	0.3839	0.5702
Labor Share	0.2817	0.3606
Capital Share	-0.015	-0.0612
Imported Inputs Share	0.0677	0.1912
External Dependence	0.1404	0.3606
Size	-0.1071	-0.3339

Table 7: Industry Level Correlations

Correlations only refer to cross industry variation. Variables that vary across countries are first averaged at the industry level. See notes in table 6 for details on how the variables are constructed.

Cost

During a sudden stop, there are massive realignments in relative prices of inputs. The real foreign exchange rate depreciates, disproportionately affecting industries that use imported goods heavily. Also the real wage rate declines, significantly affecting firms that use labor heavily. To capture these effects I include the share of labor and imported inputs used in production as captured by the input-output matrices. For completeness, I also include a control for the share of fixed capital, defined as the difference between value added, the share of materials and the share of labor. Since the interest rate affects the user cost of fixed capital, firms that rely disproportionately on fixed capital are likely to be more heavily affected.

External Dependence

Rajan and Zingales (1998) define External Dependence as

$$\text{External Dependence} = \frac{\text{Capital Expenditure - Cash Flow}}{\text{Capital Expenditure}}$$

They calculate averages of this ratio for listed firms in the US. Rajan and Zingales argue that the ratio captures technological aspects of production, in particular, the extent to which investment is front-loaded when compared to production. Everything else constant, if access to finance is more expensive, industries that require more up-front investment should do relatively worse. Dell'Ariccia et al. (2007) and Kroszner et al. (2006) have applied this insight to banking crises, and they find an important role for external dependence. For comparability, I use the same numbers for external dependence as Rajan and Zingales (1998).

Size

The empirical corporate finance literature has often focused on size as a determinant of differences in the supply of finance available to different firms.[22] Firm size can also matter because large firms are more likely to be exporters.[23] The UNIDO data include data on employment and number of establishments by industries. I calculate for each country/industry pair the average employment/establishment ratio.[24]

Trend Behavior

Different industries may have different long-run growth trends. I control for these in two ways. First, for each country/industry observation I add the average growth in the six years before the crisis as a control. This should pick up both inertia and mean reversal tendencies.

Second, I include the average growth in the industry among non-crisis countries over the same period. These are countries that have not experienced a crisis over the previous 10 years.

Normally Expected Cyclical Behavior

I construct this control as follows: First, for each country/industry observation I run the following regression:

$$y_{i,k,t+h} - y_{i,k,t-1} = \lambda_{i,k,h} + \eta_{i,k,h}(gdp_{i,t+h} - gdp_{i,t}) + \epsilon$$

where again $y_{i,k,t}$ is log value added in industry k, country i, time t and $gdp_{i,t}$ is log G.D.P. in country i time t. If there is a crisis in the country, I include in the regression for all years prior to the crisis and all years more than ten years after. For countries that do not face a crisis, I include all observations available. Since there is typically not a large number of observations for each industry, the estimates are quite noisy. I then calculate industry specific components:

$$\bar{\lambda}_{k,h} = \frac{\sum_i \lambda_{i,k,h}}{I}$$
$$\bar{\eta}_{k,h} = \frac{\sum_i \eta_{i,k,h}}{I}.$$

Lastly, I calculate the expected industry behavior within a given window following the crisis given the drop in output:

[22] See Fazzari et al. (1988) for the seminal paper and Gertler and Gilchrist (1994) for an application specific to interest rate shocks. However, see also Kaplan and Zingales (1997) for a critique.

[23] See Melitz (2003).

[24] I also experiment with the employment/establishment ratio in the year before the crisis. The results are virtually identical.

$$\text{Normally expected cyclical behavior} = \bar{\lambda}_{i,h} + \bar{\eta}_{i,h}(gdp_{i,t^*+h} - gdp_{i,t^*-1})$$

Controls for Demand

To measure the demand for durable consumer goods consumption, I assume that all the consumption from certain sectors is durable.[25]

I allow for indirect demand effects through the supply chain. As a consequence, the control variable takes into account that the demand for basic metals is heavily affected by the demand for investment goods. Let $a_{i,j}$ be the i, j^{th} entry in the matrix of technical coefficients A. If sector j produces Y_j then it uses $Y_{i,j} = a_{i,j}Y_j$ inputs from sector i. Let V_i denote the demand for final use of the products of sector i. Then it must be the case that

$$Y_i = \sum_j a_{i,j}Y_j + V_i.$$

In terms of percentage changes,

$$\frac{dY_i}{Y_i} = \sum_j a_{i,j}\frac{Y_j}{Y_i}d\frac{Y_j}{Y_j} + \frac{V_i}{Y_i}\frac{dV_i}{V_i}.$$

Let B be a matrix with entries $b_{i,j} = a_{i,j}Y_j/Y_i$, D a vector with entries Z_i/Y_i. Also (with abuse of notation), let dY/Y be a vector with entries dY_i/Y_i. Likewise, let $dV_i/V_i = dV/V$. Then

$$\frac{dY}{Y} = B\frac{dY}{Y} + \frac{dV}{V}$$

so that,

$$\frac{dY}{Y} = (I - B)^{-1}D\frac{dV}{V}$$

where I is a conformable identity matrix and (I-B) is invertible.

Thus, the elasticity of output in each sector to a given change in final demand is given by the corresponding entry in the $(I - B)^{-1}D$ vector.

It is natural to extend the framework to look at the effect of changes in different components of demand. All that is needed is to substitute D for a matrix with entries $I_{i,H}/Y_i$, I_i/Y_i and EXP_i/Y_i.

In the calibration, I use country specific input-output matrices whenever possible; otherwise I use an average for the region.[26]

[25] I define as durable consumption all the consumption of wood products, furniture, non-metallic mineral, machinery and equipment and half of Manufacturing n.e.c. I likewise use the Leontief inverse to account for indirect effects.

[26] Thus, for example, the input-output structure for Malaysia is the average between South Korea and Indonesia.

Appendix B: Setup for Quantitative Model

Model Setup

The model economy has multiple sectors. It has N_T tradable sectors and N_{NT} non-tradable sectors. The tradables correspond to the manufacturing sectors in the data, and the non-tradables are included so as to fully account for all general equilibrium effects.

Household

There is a representative household, who is able to borrow and lend abroad at an exogenous risk-less gross interest rate R_t. The household supplies labor and consumes both durable and non-durable goods. The utility function of this household is time-separable with discount rate $\beta < 1$ and the period utility is

$$u\left(C_t, K_{H,t}, L_t\right) = \frac{1}{1-\sigma}\left(\left[\gamma^{d\frac{1}{\rho}} C_t^{\frac{\rho-1}{\rho}} + \left(1-\gamma^d\right)^{\frac{1}{\rho}} K_{H,t}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} - \chi * L_t^{1+\frac{1}{\psi}}\right)^{1-\sigma}$$

where C_t is non-durable consumption, $K_{H,t}$ is the stock of durable goods held by the household and L_t is labor supply.

Production Functions

The production function of each sector is

$$Y_{i,t} \quad = \quad \prod_{v=0}^{\tau_i} Z_{i,t-v}\left(v\right)^{\omega_i(v)}, \; \sum \omega_i\left(v\right) = 1$$

where $Y_{i,t}$ is the production of the input i in t. $Z_{i,t-v}\left(v\right)$ denotes a composite of goods acquired in period $t-v$ to produce the finished good which is sold v periods ahead. It is defined as:

$$Z_{i,t-v}\left(v\right) = \gamma_i A_{t-v}\left(u_{i,t-v}\left(v\right) K_{i,t-v}\left(v\right)\right)^{\alpha_{K,i}} \left(L_{i,t-v}\left(v\right)\right)^{\alpha_{L,i}} \left(M_{i,t-v}\left(v\right)\right)^{1-\alpha_{L,i}-\alpha_{K,i}}$$

where $u_{i,t-v}\left(v\right)$ is the rate of utilization of fixed capital at t, $K_{i,t-v}\left(v\right)$ is capital stock, $L_{i,t-v}\left(v\right)$ is labor and $M_{i,t-v}\left(v\right)$ is a composite of materials produced in the different sectors. The index v implies that the input is meant for production of the output that will be available v periods in the future.

Once inputs are combined into $Z_{i,t-v}\left(v\right)$, they cannot be reassigned to a different sector or horizon. This will be important for the short-run dynamics of the model, as it will be a source of inertia both in aggregate output and in cross-sectoral reallocation.

As an accounting matter, the composite $Z_{i,t-v}\left(v\right)$ is part of inventories. In particular, in the beginning of each period, the inventories held by sector i are the sum of all $Z_{i,t-v}\left(v\right)$ with $v > 0$, properly inflated by the accumulated interest rates over the period in question.

Lastly, as a national accounting matter, the production function in this section corresponds to total output, not to the value added by the sector. To get to value added, we need to subtract from output the cost of all materials used in production and the change in inventories.

Capital Accumulation, Utilization and Maintenance Costs

Capital is sector specific and is produced by combining old capital and investment goods.

$$K_{i,t} = (1-\delta)\,K_{i,t-1} + I_{i,t} - \frac{\zeta}{2}\frac{\left(K_{i,t} - (1+g)K_{i,t-1}\right)^2}{K_{i,t-1}}.$$

Durable consumer goods are produced in a similar fashion:

$$K_{H,t+1} = (1-\delta)\,K_{H,t} + I_{i,t} - \frac{\zeta}{2}\frac{\left(K_{H,t} - (1+g)K_{H,t}\right)^2}{K_{H,t}}.$$

Whenever a firm uses capital, it has to use up spare parts in order to make up for wear and tear of the capital stock. This maintenance requirement is increasing in capacity utilization:[27]

$$\Omega_{i,t} = \frac{\mu_i}{1+\xi}\left[u_{i,t}^{1+\xi} - 1\right] K_{i,t}.$$

Composite Goods

Non-durable consumption C_t, fixed investment $I_{i,t}$, investment in durable consumption goods $I_{H,t}$, materials $M_{i,t}$ and spare parts $\Omega_{i,t}$ are composites of the goods produced in the $N_T + N_{NT}$ sectors and imported goods. These composites are represented by CES aggregates:

$$X_t = \left[\begin{array}{c} \sum_{k\in\{1,\dots,N_T+N_{NT}\}} \left(\gamma_{k,X}\right)^{\frac{1}{\rho}} \left(X_{k,X,t}\right)^{\frac{\rho-1}{\rho}} \\ + \left(1 - \sum_{k\in\{1,\dots,N_T+N_{NT}\}} \gamma_{k,X}\right)^{\frac{1}{\rho}} \left(X_{*,X,t}\right)^{\frac{\rho-1}{\rho}} \end{array}\right]^{\frac{\rho}{\rho-1}}$$

where X stands in for C, I_i, Ω_i or M_i. $X_{*,t}$ is the amount of imported goods used for the production of X and $\sum \gamma_{i,X} \leq 1$.

Resource Constraints

While capital is sector specific, there is no limit in reshuffling it for the production at different horizons. This implies the following resource constraint for capital stock for sector i:

$$\sum_v u_{i,t} K_i\left(v\right) \leq u_i K_{i,t}.$$

[27] In the calibration, I choose units so that in steady state $u = 1$ and the firm does not have any maintenance costs. This implies that spare parts needs can be negative if $u < 1$. This assumption is made for tractability, but does not have any important consequences for the results.

Raw materials respect an analogous resource constraint:

$$\sum_{v} M_{i,t} \ \leq M_{i,t}.$$

In contrast, labor is perfectly mobile between sectors. This implies the following constraint:

$$\sum_{k\in\{1,\ldots,N_T+N_{NT}\}} \sum_{v}^{n} L_{i,t}\left(v\right) \leq L_t.$$

Finally, there is a resource constraint in the non-tradable sectors. This is:

$$C_{i,t} + I_{i,H,t} + G^i + \sum_{j\in\{1,\ldots,N_T+N_{NT}\}} \left(M_{i,j,t} + I_{i,j,t} + \Omega_{i,j}\right) \leq Y_{i,t}$$

where G_i are government purchases, assumed to be constant over time.

Foreign Trade and the Current Account

Exports are identical to the total output from sector i minus the sum of the domestic demands for this good:

$$EXP_{i,t} = Y_{i,t} - C_{i,t} - I_{i,H,t} - \sum_{j\in\{1,\ldots,N_T+N_{NT}\}} \left(M_{i,j,t} + I_{i,j,t} + \Omega_{i,j,t}\right).$$

For non-tradables, exports are equal to zero:

$$EXP_{i,t} = 0 \text{ if } i \text{ is non-tradable.}$$

Total imports are the sum of all foreign produced goods demanded for different uses:

$$IMP_t = C_{*,t} + I_{*,H,t} + \sum_{j\in\{1,\ldots,N_T+N_{NT}\}} \left(M_{*,j,t} + I_{*,j,t} + \Omega_{*,j,t}\right).$$

The prices of the foreign goods are constant over time and are normalized to be equal to 1. The current account identity is

$$\begin{aligned} B_t - R_{t-1}B_{t-1} &= IMP_t \\ &\quad - \sum_{i\in\{1,\ldots,N_T\}} EXP_{i,t} + \kappa B_t^2 \end{aligned}$$

where B_t is the amount of net foreign debt that domestic households hold.

Extension Adjustment Cost to Labor

In the text I consider an extension of the model where there is an adjustment cost to labor. To model this adjustment cost, I assume that in order to increase employment in sector i from $L_{i,t-1}$ to $L_{i,t}$ it is necessary to expend $frac\zeta_L 2 \left(L_{i,t} - L_{i,t-1}\right)^2$ units of the imported good. I calibrate $\zeta_L = \zeta$.

Allocation

The allocation is the solution to a planner's problem where the planner maximizes the utility function of the household subject to all the resource constraints.

Appendix C: Details of Calibration

To calibrate the shares I use information from the same input-output matrices used to construct indicators of the demand shares. I assign to each of the manufacturing sectors in the input-output table an ISIC Rev. 2 code in order to match the data in the empirical section. The correspondence is not perfect. Some sectors that are differentiated in the empirical section, such as textiles and apparel, only appear as a single sector in the input-output matrix. On the other hand, the input-output matrix includes more machinery producing sectors than in the UNIDO data set. In this latter case, I consolidate the sectors in order to build equivalents to the ones in section 3.

The service sector is really a residual sector that includes services, retail, utilities, public administration and agriculture. I treat mining as a foreign sector since it is highly tradable and employs relatively few workers. I also experimented with treating agriculture the same way as mining. The results are not sensitive to this assumption.

The sectors that I treat as non-tradable do, in fact, trade. I treat all their sales abroad as domestic sales and all the purchases from their counterpart abroad as domestic purchases. I am still left with a (small) imbalance. Also, at the aggregate level there is a trade imbalance that does not come up in the steady state of the model. I remove these imbalances by re-scaling the size of the non-tradable sector and of domestic absorption.

I re-scale the labor shares up by a factor of 2, conforming to the findings in Young (1995) and Gollin (2002) that labor shares in developing countries are frequently underestimated because of the large number of self-employed workers. This brings the aggregate labor share close to 0.6, which is the norm for developed countries. Also, I do not allow explicitly for indirect taxes in the model, so that I split them between labor and capital income.[28] Given the input-output table, it is a straightforward matter to calculate the factor shares for the different sectors as well as the weight of each sector in each of the different composite goods. The values in the input-output matrices do not account for the opportunity cost of capital. Hence, for a manufacturing sector i, $\alpha_{i,M} = \frac{M_i}{Y_i} \times \left(\frac{\omega_i}{R} + 1 - \omega\right)^{-1}$. An analogous calculation applies to labor share and to the construction sector.

[28]For an interesting account of how heterogeneity in indirect taxes provides a foundation for fluctuations in T.F.P., see Benjamin and Meza (2009).