Financial Crises and Total Factor Productivity:
The Mexican Case

Felipe Meza

Erwan Quintin

Universidad Carlos III de Madrid

Federal Reserve Bank of Dallas[*]

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Abstract

Output falls by unusually large amounts after recent financial crisis, much more than what the behavior of capital and labor would suggest. In the language of standard development accounting, total factor productivity (TFP) falls markedly during financial crises, as we document with evidence from recent crises. These falls in TFP are intriguing because they are unusual: the fall in TFP that occurs during the first year following the crisis episodes exceeds two standard deviations in all cases. They are also puzzling because given the magnitude of the fall in TFP, a standard neoclassical model would predict that hours worked should fall much more than they do in the data. Our goal in this paper is twofold: document the unusual behavior of TFP during crises, and describe the challenge that this shock poses for standard neoclassical models. We study in detail the case of Mexico after the 1994 financial crisis. The fact that the behavior of factor series diverges so much from the predictions of standard models suggests that factor hoarding plays a large role during financial crises. Using

standard models of factor hoarding we find that capital utilization and labor hoarding account for large fraction of the variance of TFP both during and outside the crisis. But TFP adjusted for changes in factor use continues to drop by an unusual amount in 1995, and the predicted fall in output continues to exceed its data counterpart. The fact that TFP falls less is offset by the fall in factor use.

1 Introduction

Output falls by unusually large amounts during recent financial crises, much more than what the behavior of capital and labor use would suggest. In the language of standard development accounting, total factor productivity (TFP) falls very markedly during financial crisis, as we document with evidence from recent crises. These falls in TFP are intriguing because they are unusual: the deviation from TFP trend that occurs during the first year following the crisis episodes we study exceeds two standard deviations in all cases. They are also puzzling because given the magnitude of the fall in TFP, a standard neoclassical model would predict that hours worked should fall much more than they do in the data. Our goal in this paper is twofold: document the unusual behavior of TFP during crises, and describe the challenge that this shock poses for standard neoclassical models.

We make these points in the open economy neoclassical model described by Mendoza, 1991. In particular, we treat financial crises as exogenous shocks to interest rates and TFP. Most of the existing literature on financial crises focuses on what triggers the collapse in the first place. For instance, in a special issue of the *Journal of International Economics* devoted to understanding the causes of Mexico's 1994 "Tequila" crisis, Flood et al. (1996) and Calvo and Mendoza (1996) study the role played by flow imbalances (liquid financial assets vs. broad monetary aggregates for instance, or short-run debt vs. gross foreign reserves). In the same issue, Cole and Kehoe (1996) and Sachs, Tornell and Velasco (1996) conjecture that Mexico's large stock of short-term debt may have given rise to self-fulfilling *speculative attacks* against peso-denominated bonds. These and many related articles have shed some light on what causes financial collapses in nations like Mexico, but they do not try to account for the sharp drop in output that invariably follows the collapse. More recent models (see e.g. Burnside, Eichenbaum and Rebelo, 2001, Corsetti, Pesenti and Roubini, 1999, and Lahiri and Vegh, 2002) provide qualitative explanations for the contractions of output. Cavallo, Kisselev, Perri and Roubini (2004) show that large falls in output are possible, using a sticky-price model with a margin constraint. However, they do not analyze a specific episode and compare model predictions to data. Overall, and like Calvo (2000), our assessment is that there has been little emphasis on the behavior of output after financial crises. Our goal in

this paper is to contribute to filling this gap.

In order to study the real impact of financial crises, we concentrate our attention on Mexico's 1995 crisis. While financial crises share many characteristics, a satisfactory quantitative study of the real impact of these episodes must incorporate country specific features. In the case of Mexico, a number of deep fiscal shocks accompanied the financial crisis. Pressed by international organizations to improve its fiscal situation, the Mexican government decided to raise energy prices and the rate at which it taxes consumption first quarter of 1995. In our quantitative experiments, we model those shocks explictly. As a result and among other benefits, our TFP calculations control for the fact that energy use fell a lot during 1995. Our main finding is that the standard open economy neoclassical model predicts that hours worked, hence output, should have fallen much more than they did in Mexico in 1995. We also find that this result is robust to a host of calibration and modeling considerations. In particular, the result holds for various specification of preferences, and various assumptions as to the extent to which agents saw the crisis coming.

The fact that the behavior of factor series diverges so much from the predictions of standard models suggests that factor hoarding plays a large role during financial crises. One should in fact expect large swings in capital utilization and effort during crises. For several quarters, interest rates are well above trend while total factor productivity is well below trend. This gives firms strong incentives to postpone the consumption of capital services (say by leaving plants or machines temporarily idle) and economize on variable expenditures such as wear and tear until conditions improve. Similarly, employment swings may be limited due to adjustment costs, and firms may use the effort margin to adjust to the fall in the marginal product of labor. In the case of Mexico, these swings could have been magnified by fiscal shocks. For instance, the marginal returns to effort fell due to hikes in consumption and labor income tax rates. Using standard models of factor hoarding (see Greenwood and Huffman, or Burnside and Eichenbaum, 1995), we find that capital utilization and labor hoarding account for large fraction of the variance of TFP both during and outside the crisis. In particular and not surprisingly, our calculations suggest that the 1995 crisis led to big falls in capital utilization and effort. But TFP adjusted for changes in factor use continues to drop by an unusual amount in 1995, and the predicted fall in output continues

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to exceed its data counterpart. The fact that TFP falls less is offset by the fall in factor use.

These results show that the behavior of TFP during financial crises is not only unusual in a statistical, time-series sense. It is also puzzling in that given the magnitude of the TFP drop, standard variations on the neoclassical growth model all predict than output should fall much more than it does in the data. This suggests to us that understanding the real impact of financial crises will require some modeling of the allocation of resources on a more disaggregated level.

Other recent papers are seminal in the study of output in the Mexican case. Burstein, Eichenbaum and Rebelo (2002) focus on the difference between the rate of depreciation of the Peso and the rate of inflation during 1995, in Mexico and South Korea. They also analyze the behavior of output. They present a model with four sectors: local, export, tradable and non-tradable goods. The exogenous shock in their model is the tightening of an external borrowing constraint. They present results for two main variants of their model: with and without credit market frictions. They model credit market frictions in a reduced-form way, assuming the devaluation of the peso is associated with a fall in total factor productivity in the export sector. The version with credit market frictions produces yearly falls in output slightly bigger than the one observed in Mexico: -7.36% versus -6.37%.[1] This model is successful in predicting falls in output of similar magnitude as observed. However, there is an important shortcoming: the required fall in TFP in the export sector is very large: -50.3% in one year. They report no evidence of such a fall in productivity. [2] Mendoza (2002) shows that there can be large falls in output in a flexible-price model with a liquidity constraint. His objective is to show that sudden stops of capital flows can be the outcome of the dynamics of a real business cycle model. He calibrates his model using Mexican data and carries out simulations in which the economy goes from a best to a worst state in terms of high interest rates, low productivity and high consumption taxes. He shows that large falls in output are possible. However, he does not simulate the Mexican crisis and compare model

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[1]The authors report the annual fall in GDP between 1994 and 1995 in aggregate, not per capita terms.

[2]Additionally, the model predicts a fall in tradable output much bigger than observed: -8.98% versus -4.38%. The version of their model without credit market frictions is also partially successful at accounting for the behavior of output. Total output falls by 2.65% in the model versus 6.37% in the data. However, the model predicts a very large increase in tradable output, whereas it fell by a significant amount in the data: 24.06% versus -4.38%.

predictions to data. Regarding productivity, he sets the standard deviation of productivity shocks to mimic the standard deviation of tradable-goods GDP in Mexico. Finally, the work of Bergoeing et al. (2002) has some similarities with this paper. They analyze different explanations for the different growth paths followed by Chile and Mexico since 1980. They find that productivity can largely account for the behavior of Mexican output.

The two papers most related to ours are Cook and Devereux (2004) and Gerter, Gilchrist and Natalucci (2003). Cook and Devereux use a dynamic general equilibrium model of a small open economy to simulate the Asian crises in Malaysia, South Korea and Thailand. They show that in their model an increase in a country's exogenous risk premium as large as in the data can lead to output falls as big as observed ones. However, they do not consider the fluctuations of TFP in their simulations. In this paper we show that there is evidence that TFP fell by infrequently large amounts in the year after the Asian financial crisis. The paper by Gertler, Gilchrist and Natalucci (2003) presents a dynamic general equilibrium model that incorporates a financial mechanism that magnifies the quantitative effect of an increase in the exogenous risk premium. They show that their simulation of the financial crisis in South Korea produces falls in output as large as observed. They assume TFP is constant based on the following reasoning. They report that labor productivity (not TFP) fell by a large amount in Korea after the financial crisis of 1997. Their model includes variable capital utilization, modeled exactly as in our paper. They show that the risk premium shock leads to a fall in utilization. Then they add that this fall in utilization can account for the behavior of measured labor productivity, i.e. output per worker measured ignoring utilization. This result is in contrast with ours. We find that variable capital utilization can account for less than one third of the fall in measured TFP. Additionally, introducing TFP measured considering variable capital utilization into the model as an exogenous shock leads to falls in output that are much bigger than those observed.

2   Evidence

In this section we document the fact that financial crises are followed by unusually large drops in TFP and GDP using evidence from Mexico's 1994 crisis, and from the 1997 crisis

in South Korea and Thailand. We also present some evidence that these falls are persistent. Both GDP per capita and TFP remain below trend for several years after the crisis.

To measure TFP, we use the following specification of aggregate technological opportunities:

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha},$$

where Y_t denotes GDP at date t, K_t is aggregate capital, L_t denotes aggregate hours worked and $\alpha \in (0,1)$ measures the importance of capital in production. We assume like Chari et al. (2004) that A_t, aggregate TFP at date t, equals $z_t(1+\gamma)^t$, where z_t is stationary and $\gamma \geq 0$ is an exogenous trend. Let y_t, k_t and l_t denote the per capita counterparts of Y_t, K_t and L_t, respectively. In the neoclassical growth model, per capita output and capital grow at constant rate γ along the balanced growth path, while per capita hours worked are constant. Letting $\widehat{y}_t$ and $\widehat{k}_t$ be detrended per capita output and capital, we have

$$\widehat{y}_t = z_t \widehat{k}_t^\alpha l_t^{1-\alpha}.$$

In order to measure z_t, we need empirical counterparts for $\widehat{y}_t, \widehat{k}_t$ and l_t. We constructed capital stock series a perpetual inventory approach with geometric depreciation and yearly data from the International Financial Statistics database (IMF 2004). We assume that capital depreciates at a yearly depreciation rate of 8%.[3] Capital formation series begin in 1963 for Mexico and Thailand, and 1966 for South Korea. GDP series start in 1950 for Mexico and Thailand, and in 1953 for South Korea. For Mexico, we measure total hours as in Bergoeing et al. (2002) as the product of total employment and average hours per worker in the manufacturing sector as estimated with Manufacturing Survey data [explain a bit]. Calculations are similar for South Korea and Thailand except that an estimate of average hours worked is available for most sectors in those two countries.[4] Labor series can

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[3]We follow the procedure in Bergoeing, Kehoe, Kehoe and Soto (2002) to obtain time series on real gross fixed and gross capital formation.

[4]For South Korea we use data on total employment and average hours worked per week, as reported by the South Korean National Statistical Office. Total employment corresponds to employed individuals in all sectors, of age 15 and higher. Average hours worked correspond to all industries, excluding agricultural activities. Data were downloaded from http://www.nso.go.kr. For Thailand total employment corresponds to employed individuals in all sectors, of age 13 and higher, as reported by the International Labour Office (ILO) and the Thai National Statistical Office. Average hours worked correspond to all industries, exclud-

be constructed for the 1980-2000, 1970-2002 and 1989-1999 time periods in Mexico, South Korea and Thailand, respectively.

We calculate y_t, k_t, and l_t by dividing Y_t, K_t and L_t by the number of adults between ages 15 and 64.[5] Population series for the three countries start in 1960. To calculate detrended variables $\widehat{y}_t$ and $\widehat{k}_t$ we divide y_t and k_t by the average geometric growth factor of y_t in the period before the crisis episode. For Mexico the growth rate between 1960 and 1994 is 1.7%. For South Korea the growth rate between 1960 and 1997 is 5.3%. For Thailand the growth rate between 1960 and 1997 is 4.4%. Finally, we need to a value for capital share α. Gollin (2002) finds that after distributing the income of the self-employed to capital and labor income, labor income shares do not vary much across countries and time, and take values around 70%. Correspondingly, we set $\alpha = 0.3$.[6] Given the resulting samples for $\widehat{y}_t$, $\widehat{k}_t$, and l_t we can measure TFP z_t for the periods 1980-2002, 1970-2002 and 1989-1999 for Mexico, South Korea and Thailand, respectively.

Figure **??** shows the resulting series for Mexico, Thailand and Korea with vertical lines marking the onset of the financial crisis. Output falls by over 10% in all countries in the year following the crisis, over 15% in Thailand. Capital on the other hand falls little during the crisis in all countries, and hours fall much less than output in all cases. In fact, in Mexico and Thailand, hours worked fall by less than 2%. In Korea hours worked fall by a larger 7% in 1998, but this only half the fall in output. Since capital and labor fall little during crises, TFP has to fall a lot to account for the fall in output. If fell by 15% in Thailand in 1998, 7% in Korea and 8.6% in Mexico in 1994. The magnitude of these falls is very unusual for all countries. Falls in GDP and TFP exceed two standard deviations in all cases. They are also the largest falls in all our samples, with the exception of the GDP fall in Korea in 1998. Finally, notice that the falls output and TFP triggered by crises are persistent. They remain below trend in all cases for several years. For Mexico, these two variables had not recovered to their pre-crisis level by 2000, the year in which our sample of z_t ends.

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ing agricultural activities and public administration, as reported by the ILO. Data were downloaded from http://www.nso.go.th and http://laborsta.ilo.org.

[5]We use population data for Mexico as reported by Bergoeing et al. (2002). For South Korea, data were downloaded from http://www.nso.go.kr. For Thailand, data were obtained from the World Bank Development Indicators CD (World Bank 2004).

[6]Young (1995) arrive a value of $1 - \alpha = 0.703$ for Korea with data from the 1966-1990 time period.

[Figure 1: Levels of $\widehat{y}_t$ and z_t]

Naturally, these results could be sensitive to some of the measurement assumptions we have made. Young (1995) argues for instance that data on changes in inventories are of very poor quality in East Asia. We constructed alternative capital stock measures for each country excluding changes in inventories with negligible consequences on our results.[7] We also experimented with detrending factor $1+\gamma = 1.02$ which is the value Kehoe and Prescott (2002) propose.[8] Results are unchanged with one exception. In the case of South Korea, the effect of the 1997 becomes less persistent as $\widehat{y}_t$ and z_t surpass their 1997 levels by the 2000. Next, we redid all our calculations using national sources of data for $\widehat{y}_t$ and $\widehat{k}_t$.[9] Using national sources leads to much shorter time series because countries modify their systems of national accounts every now and again. This makes results more sensitive to the choice of initial capital. On the other hand, IMF data include only the most basic national accounts variables. National accounts allow us to construct better empirical counterparts for theoretical variables, which is part of the calibration procedure we undertake in the sequel, as in Cooley and Prescott (1995). To construct the empirical counterpart of $\widehat{y}_t$, we subtract indirect business taxes and impute the return to government capital and the return plus depreciation of the stock of durable goods. To construct $\widehat{k}_t$ we take into account private and public investment as well as purchases of durable goods, all accumulated with different depreciation rates. The behavior of detrended series changes little. It is still the case that the falls in $\widehat{y}_t$ and z_t after financial crises are unusually large.

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[7]Our TFP findings for South Korea can be compared to the results in Young (1995). His goal is to isolate the main sources of growth in the period 1966-1990 for four East Asian countries, including South Korea. He reports that the average logarithmic annual growth rate of $z_t^{1-\alpha}$ in South Korea was 1.7% between 1966 and 1990. The main difference between his calculations and ours is that he takes into account changes in the quality labor and capital. After excluding inventory changes as he does, we calculate that the average logarithmic annual growth rate of $z_t^{1-\alpha}$ for South Korea for the period 1970-1990 is 2.6%. The difference is large and is due to Young's adjustment for quality. Assuming a labor income share of 70% and using Young's data on raw inputs, we find that $z_t^{1-\alpha}$ in South Korea grew at an average rate of 2.7% between 1970 and 1990. In other words, our measurement of TFP leads to the same growth rate as the one found in Young (1995) if no adjustment for input quality is made. It would be interesting to measure how much quality-adjusted labor changes after financial crisis episodes. It can be the case, for example, that less skilled workers are laid off in a higher proportion after a financial crisis. It can also be the case that labor market regulations prevent firms from discriminating among workers.

[8]This is the U.S. trend. They interpret productivity as the stock of knowledge useful in production and argue that knowledge is not country-specific.

[9]Mexican data was downloaded from http://dgcnesyp.inegi.gob.mx. South Korean data was downloaded from http://www.nso.go.kr. Thai data was downloaded from http://www.nso.go.th.

In summary, we show that recent financial crises triggered unusually large falls in detrended GDP per capita and TFP in Mexico and East Asia. There is also some evidence that these falls are persistent. These findings beg several interesting questions. In the remainder of the paper, we study whether small open economy neoclassical models can account for the behavior of GDP in the Mexican case.

3   The open economy neoclassical model

In this section we evaluate the consistency of the open economy neoclassical model (as formulated for instance by Mendoza, 1991) with the behavior of output during financial crises. We model crises as exogenous shocks to TFP and interest rates. We describe a procedure to measure the magnitude of those shocks in the case of Mexico's 1995 crisis. Feeding the resulting shocks in the model yields paths for endogenous variables that we compare to data. We find that given the size of the TFP shock, the neoclassical model predicts that output should have fallen much more than it did in 1995 in Mexico. We also find that this result is robust to even large changes in parameters, in the specification of preferences, and in the specification of aggregate technological opportunities.

Because Mexico underwent deep fiscal changes in 1995 as part of the government's response to the crisis, we study a benchmark model where agents face distortionary taxes on consumption, capital income, and labor income. Also for fiscal reasons, Mexico's government significantly raised energy prices in Mexico. To control for the impact of this shock, we model the role of energy in production. Incorporating these elements will enable us to measure the quantitative impact of fiscal shocks on the behavior of output in Mexico in 1995.

While introducing distortionary taxes complicates computations a great deal by preventing us from solving the standard planner's problem, we believe that the exercise we have in mind cannot be carried out meaningfully without that feature. Massive fiscal shocks hit the Mexican economy in 1995. That models that do not model these shocks fail to explain the behavior of real activity in Mexico during that year would not appear very surprising.

3.1 Benchmark model

Consider an economy in which time is discrete and infinite. The economy contains a continuum of mass one of identical households, and a continuum of mass one of identical firms. Households live forever. They order consumption and labor supply sequences $\{c_t, l_t\}_{t=0}^{\infty}$ according to the following intertemporal utility function:

$$\sum_{t=0}^{+\infty} \beta^t \log \left(c_t - \frac{\rho}{\nu} l_t^{\nu} \right),$$

where $\beta \in (0,1)$ is the discount factor, $\nu > 1$ determines the wage elasticity of labor supply and $\rho > 0$ measures the disutility from working. With these preferences, labor supply depends only on the current wage, w_t, and is independent of consumption or income. These preferences are commonly used in small open economy models (see e.g. Mendoza (1991) and (2002), Correia, Neves and Rebelo (1995) and Neumeyer and Perri (2001)). Correia, Neves and Rebelo (1995) argue that they improve the ability of small open economy models to replicate business cycle properties.

Households have access to a perfect international capital market where one-period risk-free claims to a unit of the consumption good can be traded at an exogenous rate r_t at the beginning of period t. We denote by a_t the risk-free asset holdings of households in period t. Households can also invest in physical capital, which they sell to firms at price $1 + r_t^k$. Let k_t be the quantity of capital held by households in period t. Adjusting capital across periods carries cost

$$\frac{\psi}{2} (k_{t+1} - k_t)^2,$$

where $\psi > 0$. As is well-known, adjustment costs are necessary in open economy models to prevent investment from being counterfactually volatile. Assuming that adjustment costs are borne by households rather than firms is immaterial. An equivalent decentralization would have firms make investment decisions and bear adjustment costs. The specification we use shortens the exposition by keeping the firm's problem static. Households also face three types of taxes. In period t, consumption is taxed at rate τ_t^c, labor income is taxed at rate τ_t^l, and returns on physical capital and international assets are taxed at rate τ_t^k. Therefore,

households face the following budget constraint at date t:

$$c_t \left(1 + \tau_t^c\right) + k_{t+1} + a_{t+1} = l_t w_t \left(1 - \tau_t^l\right) + a_t (1 + r_t \left(1 - \tau_t^k\right)) + k_t (1 + r_t^k \left(1 - \tau_t^k\right)) - \frac{\psi}{2} \left(k_{t+1} - k_t\right)^2 .$$

At date t, firms transform physical capital k_t^f, energy e_t and labor n_t into quantity $y_t \equiv z_t \left(k_t^f\right)^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e}$ of the consumption good, where z_t is TFP and $\alpha_e + \alpha_k + \alpha_n = 1$. We assume that energy is available perfectly elastically at price p_t^e in date t and that fraction $\delta > 0$ of the physical capital firms purchase from households depreciates within each period. Therefore, at date t, firms choose (n_t, k_t^f, e_t) to maximize:

$$z_t \left(k_t^f\right)^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e} + (1 - \delta)k_t^f - k_t^f \left(1 + r_t^k\right) - n_t w_t - e_t p_t^e.$$

The government, for its part, collects tax revenues $\tau_t^c c_t + \tau_t^l l_t w_t + \tau_t^k \left(a_t r_t + k_t r_t^k\right)$ at date t. We assume for simplicity that these revenues are dissipated. This is without loss of generality in this model because labor supply is independent of consumption and income given our formulation of preferences.

We now define an equilibrium under the simplifying assumption that agents perfectly foresee the path of TFP, taxes and all prices. In the quantitative section, we consider other assumptions on expectations. Given an initial stock of capital and initial international assets (k_0, a_0), an equilibrium in this environment is sequences of wages and prices of capital $\{w_t, r_t^k\}_{t=0}^{\infty}$, consumption, labor supply and savings sequences $\{c_t, l_t, k_{t+1}, a_{t+1}\}_{t=0}^{\infty}$, and sequences of labor, capital and energy demands $\{n_t, k_t^f, e_t\}_{t=0}^{\infty}$ such that, given prices:

1. $\{c_t, l_t, k_{t+1}, a_{t+1}\}_{t=0}^{\infty}$ solve the household's problem;
2. $\{n_t, k_t^f, e_t\}_{t=0}^{\infty}$ solves the firm's problem for all t;
3. The market for physical capital clears: $k_t = k_t^f$ in all t;
4. The labor market clears: $n_t = l_t$ in all t;

We will now ask whether this benchmark model can account for the behavior of output, labor, capital and energy after Mexico's Tequila Crisis.

3.2 Data and calibration

In order to compute the predictions of this benchmark model for output and hours in Mexico in 1995, we first need a path for TFP in Mexico that is consistent with the theory. This requires a few adjustments to the procedure we used in the previous section. Date t TFP in the benchmark model is:

$$z_t = \frac{y_t}{k_t^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e}}.$$

Therefore, we need empirical counterparts for the theoretical variables y_t, k_t, n_t, and e_t. Appendix A describes the procedure we use in some detail. Our basic approach closely follows Atkeson and Kehoe (1999). We use quarterly data to construct the empirical counterparts of theoretical variables. There are four key conceptual differences between GDP as reported in the Mexican national accounts (*measured GDP*) and output y_t in the model. First, y_t equals the sum of payments to labor, capital and energy, i.e. $y_t = w_t r_t + r_t^k k_t + p_t^e e_t$. GDP, on the other hand, treats energy as an intermediate output and thus corresponds to $y_t - p_t^e e_t = w_t r_t + r_t^k k_t$. Second, there is no energy-producing sector in the model, whereas measured GDP includes the value added by the energy sector. Third, measured GDP includes indirect business taxes (IBT), whereas output y_t does not. The fourth and final difference is that output in the model includes the return to all capital in the economy, whereas measured GDP does not. It excludes the return on government capital and the return plus depreciation of the stock of durable goods. We make the four corresponding adjustments to measured GDP to construct a measure of output consistent with y_t. We call this adjusted GDP *measured gross output*. We also construct capital, labor and energy series that are consistent with the model. In particular, we take into account the fact that in the model there is no energy-producing sector, and that in the model only firms use energy.

Besides empirical counterparts for y_t, k_t, n_t, e_t, we need three technological parameters before measuring TFP. We assume the share of labor income in GDP is 0.7. This assumption is supported by the work of Gollin (2002), who finds that, after adjusting labor income taking into account the income of the self-employed, labor income shares take values around 70%, across a large set of countries, and across time. We assume that the share of labor income

in the energy-producing sector in Mexico is also 70%.[10] Given these assumptions, the shares income in measured gross output are

$$\alpha_n = 0.7\frac{GDP}{Measured\ gross\ output} = 0.6644,$$

$$\alpha_k = 0.3\frac{GDP}{Measured\ gross\ output} = 0.2848,$$

$$\alpha_e = \frac{Energy\ expenditure}{Measured\ gross\ output} = 0.0508.$$

We now turn to measuring the empirical counterparts of exogenous shocks in the model, other than TFP: international interest rates, the price of energy and taxes. We calculate interest rate r_t in period t as

$$r_t = \frac{(1 + Tbill\ rate_t)(1 + MX\ Brady\ spread_t)}{1 + US\ inflation_t} - 1,$$

where $Tbill\ rate_t$ is the interest rate on US Treasury bills, $MX\ Brady\ spread_t$ is the spread between the return paid by Mexican Brady bonds and the interest rate paid by US Treasury bills, and $US\ inflation_t$ is the relative change in the US GDP deflator. In other words, our proxy for r_t is the real return paid by Mexican Brady bonds.[11] Our sample of Mexican Brady bond data starts in the last quarter of 1990 and ends in the first quarter of 2003. We calculate the price of energy as a weighted average of the nominal price of natural gas, gasoline and electricity divided by Mexico's GDP deflator.[12] In our quantitative experiments, we scale the relative price of energy to match the average energy use level prior to 1995. We calculate taxes on consumption, labor income and returns from capital and international assets using the method of Mendoza, Razin and Tesar (1994).[13] The calculated taxes are

[10]Verifying that this assumption is appropriate is difficult in the case of Mexico since Mexican national accounts do not provide compensation of employees of the oil and electricity companies run by the government.

[11]Neumeyer and Perri (2001) use a similar construct to study the relationship between business cycles and international interest rates in developing countries. The rates we use are end of quarter rates, using average rates does not alter our quantitative findings.

[12]We follow the method used by Atkeson and Kehoe (1999). We are constrained to use yearly data on prices and sales of energy to calculate the average price of energy. We assume that the nominal prices of different kinds of energy remain constant throughout each year. The Mexican government typically adjusts energy prices either at the end or at the beginning of each year.

[13]Only data on total income tax revenues is available in Mexico. We follow the estimate reported in Fernandez and Trigueros (2001) to split total income tax revenue into its components: individual and

average effective tax rates, i.e the ratio of tax revenue to tax base. In the next figure we plot the empirical counterparts of the exogenous shocks.

[Figure 2: Plotting shocks (this is a plot with a lot of information)]

Figure **??** reveals that most of these series underwent unusually large changes in 1995. In particular, and not surprisingly given the fact that capital and labor fall much less than output during 1995, TFP falls markedly during the crisis. Measured gross output fell 10.1% between the last quarter of 1994 and the last quarter of 1995, while capital fell by 0.7%, labor fell by 2.5%, and energy fell by 24.4%. Given these data and our calculated technological shares, TFP must fall by 7.1% to account for the fall of measured gross output in 1995. Interest rates measured in annual terms rise from 8.7% on average during 1994 to 19.5% in the first quarter of 1995. The price of energy jumps by 43% between the last quarter of 1994 and the first quarter of 1995, while the tax on consumption rises from 10.4% to 13.3% from the last quarter of 1994 to the first quarter of 1995. On the other hand, the tax rate on labor shows almost no change, falling from 12.5% to 12.2% between 1994 and 1995. The tax rate on capital and asset returns falls from 9.5% to 7.4%.

Overall, the Mexican economy underwent a number of severe negative shocks in 1995. We will now argue that given the magnitude of these shocks, the neoclassical growth model predicts that GDP should have fallen much more than they did in 1995 in Mexico. We will also argue that the quantitative impact of changes in fiscal policy is small compared to the role of TFP. To make these points, we first need to calibrate preference and adjustment cost parameters. One way to calibrate the model would be to assume that at a given date Mexico was on a balanced growth path. However, we do not think that such an assumption is appropriate. Mexico underwent a series of deep crises in the 1980s after decades of brisk growth. Between 1980 and 2003, GDP per capita did not grow in Mexico, and we do not believe this to be a balanced growth path. Our calibration strategy consists of choosing parameter values to match the statistical properties of input use and measured gross output before 1995.[14]

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corporate. We use these components to measure the tax rate on labor income, and on capital and asset returns. Also, when measuring consumption taxes using OECD data, Mendoza et al. (1994) exclude the "other taxes" item. Because this last item is large in magnitude in Mexico, we choose to include it.

[14]Bergoeing et al. (2002) follow a different calibration procedure. Their main objective is to allow for a comparison between Mexico and Chile over the past two decades. For some parameters, they impose values;

Preference parameters ρ and ν determine the level and volatility of labor supply, respectively. We set ρ to match the average of our measure of hours worked per working age adult before 1995. As for ν, we begin by setting $\nu = 1.5$, which implies a wage elasticity of labor supply of 2, the value used in Mendoza (1991). It falls within the range mentioned by Greenwood, Hercowitz and Huffman (1988), who cite studies of labor supply in the U.S. Unfortunately, we were unable to find similar studies for Mexico. In this benchmark model the predicted path for input and output series is independent of β. We simply set it as in Correia, Neves and Rebelo (1995) to satisfy $\beta \left[1 + r \left(1 - \tau^k \right) \right] = 1$, where r and τ^k are the long run values of the international interest rate and the tax on the return on international assets. In our model, the accumulation of international assets is affected by τ_t^k, which we have to take into account when calibrating β. This assumption on β implies that the steady state growth rate of consumption is zero. To obtain a long run value for the interest rate, we assume that the value it takes in the first quarter of 2003 (0.9% at a quarterly rate), the last date in our sample, will be Mexico's cost of international funds in the future. We also use the last value for τ_t^k in our sample (9.1%) as the long run value of the tax on capital income. Regarding the capital adjustment cost parameter ψ, we choose its value to match the observed standard deviation of the investment-to-measured gross output ratio before 1995.

Having set all parameters, we can now calculate the path our model predicts for input use and output under various assumptions on agents' expectations. In all our experiments, the initial period corresponds to the last quarter of 1990. In the first experiment (Perfect foresight, PF) we assume that in the first period agents know the entire sequence of exogenous shocks shown in figure **??**. In our second experiment (Perfect surprise, PS) we assume instead that agents know all shocks up to the last quarter of 1994, but then expect shocks to assume their average pre-crisis values indefinitely. That is, agents do not expect a crisis to occur in 1995. When they observe the values of shocks in the first quarter of 1995, agents immediately revise their expectations to the path actually observed. We view this as approximating a situation where households assign a positive but very small probability to the possibility of a crisis in 1995. These assumptions on expectations enable us to use nonlinear methods based

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For other parameters, they calculate average values using first order condition evaluated at different dates.

on Euler equations. Specifically, the evolution of capital in this model boils down to the following second-order difference equation for all t:

$$1 + r_{t+1}(1 - \tau_{t+1}^k) = \frac{1 + \left(\alpha_k \frac{y_{t+1}}{k_{t+1}} - \delta_{t+1}\right)\left(1 - \tau_{t+1}^k\right) + \psi\left(k_{t+2} - k_{t+1}\right)}{1 + \psi\left(k_{t+1} - k_t\right)}. \qquad (3.1)$$

Given the initial level of capital, we use a shooting algorithm to find the path of capital such that endogenous variables converge to steady state levels assuming that exogenous variables stay at their 2003Q1 levels for ever. Appendix B provides the details. The equilibrium path for capital and other endogenous variables can then be calculated using exact methods (up to the precision of the computer for simple arithmetic operations.) Given the magnitude of shocks in 1995, linear approximations around the steady state could yield inaccurate results.[15]

3.3 Results

Figure 3 plots the predictions of the model for GDP, labor, the capital-output ratio, and energy, for both the PF and PS experiments, and compare them to data. Simulated GDP corresponds to $y_t - p_t^e e_t$. Data on GDP corresponds to measured gross output minus energy expenditure. Each time series is scaled by its respective value in the last quarter of 1994. This makes it easier to compare the contraction of economic activity in the model and in the data.

Our key result is GDP, labor, the capital-output ratio and energy fall more than twice as much in percentage terms as in the data. For instance, under both expectation scenarios, GDP falls by about 10% in the data compared to almost 21% in the model. This is true, that is, whether or not agents saw the crisis coming. The main difference between the two experiments is the predicted path for the capital-output ratio. In the PF experiment, the ratio falls more rapidly before 1995 as agents anticipate the crisis. This makes all variables fall in anticipation of the large changes in exogenous variables in 1995. The ratio predicted

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[15]Dotsey and Mao (1992) find that the accuracy of linear approximation methods worsens as the variance of shocks rises. Also complicating the analysis is the fact that allocations in our model do not solve a modified social planner's problem due to the presence of distortionary taxes.

by the PS experiment tracks observed capital more closely.

To measure the relative role of each of the many shocks that hit the Mexican economy in 1995, we carried out PF experiments in which only one of the exogenous variables changes after the last quarter of 1994, while other variables remain constant at their values in the last quarter of 1994. We find that changes in the capital tax and the labor tax had little effect on the behavior of GDP in 1995. Shocks to the consumption tax, interest rates and the price of energy yielded more pronounced falls in output: -2.9%, -2.2% and -1.4% during 1995 respectively.[16] The impact of TFP outweighs that of all other shocks combined. Holding other exogenous variables at their end-of-1994 values, TFP alone would have caused GDP to fall by 15.4% in 1995 relative to 1994. It is in other words the magnitude of the TFP shocks that accounts for the model's counterfactually large fall in output. In particular, the benchmark model's difficulties in matching the behavior of output and input use during Mexico's 1995 crisis does not stem from fiscal shocks.

The remainder of this paper is devoted to evaluating the robustness of these findings to our assumed parameter values and to our assumptions on technological opportunities and preferences.

4 Robustness

4.1 Optimistic expectations

Even under our perfect surprise scenario, the model does not predict the rise in the capital-output ratio prior to the crisis one observes in the data. It may be the case, therefore, that agents' expectations were more optimistic than assumed in our PS calibration. To verify this, we ran a perfect surprise experiment assuming that agents expected a constant level of (low) interest rates after 1994 that yields a path for capital before the crisis that is consistent with the data.[17] Figure ?? shows that in that fashion one can generate a path for the capital output ratio capital that approximates rather well the true path before the crisis.

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[16]We take into account that keeping the interest rate fixed at its (high) value in the last quarter of 1994 induces a trend in endogenous variables. Results are reported net of this trend.

[17]Alternatively, modifying expected TFP values leads to similar results.

[Figure 4: results from optimistic expectations, benchmark model]

Under these assumptions on agents' expectations, the fall in output during 1995 is approximately of the same magnitude as in the two previous experiments. Investment falls more, because more capital had been accumulated anticipating low levels of the interest rate. In sum, specifying expectations so as to match the behavior of the capital before the crisis does not improve the model's performance following the crisis.

4.2 Elasticity of labor supply

Our findings could be sensitive to the assumed elasticity of labor supply. In particular, a higher ν would render labor supply less elastic, which should reduce the predicted fall in hours worked, hence in output in 1995. In fact, it should be clear that one can find a value for ν such that the model will predict the correct fall in hours worked during the crisis. Figure ?? shows that setting $\nu = 4.33$, which is at the upper bound of the estimates available for the United States, produces a fall in hours in 1995 that resembles the fall in the data.[18]

[Figure 5: low elasticity results with benchmark model]

But such a value for ν predicts a counterfactually stable path for the labor input outside the crisis. Its standard deviations in the samples 1990.4-1994.4 and 1990.4-2003.1 are much smaller than the ones observed, as can be seen in the figure. In short, it is not possible to find a value for ν so that the model yields a reasonable path for hours work both during and outside of the crisis period.

4.3 Standard preferences

Heretofore we have assumed preferences such that the wage elasticity of the labor supply is exogenous and invariant over time. Correia et al. (1995) find that these preferences improve the model's consistency with business cycle facts. It is interesting nonetheless to consider the impact of giving households preferences that are more standard in closed economy exercises. Specifically, assume that households now order consumption and labor supply sequences

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[18]Greenwood et al. (1988) report a range of values for the elasticity of labor supply. The maximum value of ν implicit in their work is 4.33.

$\{c_t, l_t\}_{t=0}^{\infty}$ according to the following intertemporal utility function:

$$\sum_{t=0}^{+\infty} \beta^t \left\{ \log c_t + \rho \log(1 - n_t) \right\},$$

where $\rho > 0$ measures the disutility associated with working. Household face the same budget constraint as before. Solutions to the household problem must satisfy, for all t:

$$\frac{c_{t+1}}{c_t} = \frac{\beta(1 + \tau_t^c)}{1 + \tau_{t+1}^c}(1 + r_{t+1}(1 - \tau_{t+1}^k)) \tag{4.1}$$

$$\frac{\rho c_t}{1 - n_t} = \frac{w_t(1 - \tau_t^l)}{1 + \tau_t^c}. \tag{4.2}$$

Both conditions have the usual interpretation. The first says that the marginal rate of substitution between consumption in two consecutive periods must equal the return on savings (the marginal rate of transformation between date t and date $t + 1$ consumption). The second equates the marginal utility of leisure in each period to its opportunity cost, the net wage times the marginal utility of consumption. Using first order conditions for profit maximization by firms (those are unchanged), (4.2) can be rearranged to read:

$$n_t = \left(1 + \frac{(1 + \tau_t^c)\rho c_t}{(1 - \tau_t^l)\alpha_n y_t}\right)^{-1} \tag{4.3}$$

Condition (4.3) shows how standard preferences could help account for the behavior of hours worked in 1995. Hours worked are now a simple function of the consumption-output ratio. If the model predicts a fall in consumption comparable in size to the fall in output in 1995, the model will also predict little change in hours, as in the data.

Computing the model requires solving for a path of consumption, hours worked and capital that satisfies (4.1), (4.3) and the same difference equation in capital as before. In implementing the algorithm described in appendix B, we set ρ to match the average level of hours worked before the crisis. We also choose the initial level of asset a_0 so that the model implies an approximate debt to GDP ratio of 35% for Mexico in 1994, as in the data.[19]

As before, we can compute a path for endogenous variables under two expectation sce-

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[19]This is approximately the value reported in Lane and Milesi-Ferretti (2001).

narios. The model with standard performs very poorly under perfect foresight. Indeed, consumption then rises at the rate of interest net of the rate of time preference. Since interest rates are high in 1995, consumption rises throughout the year while TFP falls markedly. Correspondingly, the consumption- output ratio rises markedly and hours worked fall even more drastically than in the previous model. Those results are available upon request. Under perfect surprise assumptions however, agents adjust consumption in the first quarter of 1995 after discovering the true path of exogenous series. In particular, consumption must be adjusted downward which could mitigate the impact on hours worked. Figure ?? shows the results. Since the path of energy is little changed relative to previous experiment, we replace that panel of the figure with the consumption-income ratio, as this is the crucial statistic in this model. The consumption adjustment in the first quarter of 1995 is such that the consumption-output ratio actually falls, so that hours *rise* in the first quarter. But this effect is short-lived, as consumption then starts rising steeply due to high interest rates. Hours adjust downward after one quarter, as does output. In other words, once agents have adjusted to the crisis, hours and GDP fall as much as in the benchmark model. Overall, the predicted fall in those series continues to significantly exceed their empirical counterparts.

4.4   Factor hoarding

Financial crises create optimal conditions for big swings in factor utilization. Since TFP is very low for a few quarters, direct returns to capital utilization are low. On the other hand, the opportunity cost of capital is high during crises since interest rates are high, so that the variable costs associated with high utilization (due, say, to wear and tear) are high. These gives agents strong incentives to postpone the consumption of capital services until business conditions improve. Likewise, labor services could be hoarded as effort falls. Employment adjustment may be limited due to adjustment costs, and agents may use the unobservable effort margin to adjust to the marked fall in labor productivity. In the case of Mexico, the fall in effort could be compounded by the fact that labor income and consumption became more heavily taxed in 1995. Our goal in the next few paragraphs is to quantify the importance of these effects in standard models of factor hoarding.

4.4.1 Endogenous capital utilization

We model capital utilization as in Greenwood et al. (1988). Household preferences are the same as in the benchmark model. However, we now assume that firms can alter the rate at which they utilize capital. Raising utilization in a given period raises output, but it also raises the quantity of capital lost to depreciation. The depreciation rate of capital is a function of utilization:

$$ u_t = \frac{u_t^{\phi}}{\phi}, $$

where $\phi > 1$ and $u_t > 0$ is the rate of utilization in period t. Output at date t is now given by:

$$ z_t^u \left(u_t k_t^f \right)^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e} + \left(1 - \frac{u_t^{\phi}}{\phi} \right) k_t^f, $$

where $u_t \geq 0$ is the rate of utilization in period t, and $\phi > 1$ measures the effect of utilization on depreciation. Firms continue to take all prices as given and choose $k_t^f, n_{t,} e_t$ and u_t each period to maximize:

$$ z_t^u \left(u_t k_t^f \right)^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e} + \left(1 - \frac{u_t^{\phi}}{\phi} \right) k_t^f - k_t^f \left(1 + r_t^k \right) - n_t w_t - e_t p_t^e, $$

which yields the following condition for optimal utilization:

$$ u_t = \left(\alpha_k \frac{y_t}{k_t} \right)^{\frac{1}{\phi}}, \tag{4.4} $$

as in Greenwood et al. (1988). In the context of this model, therefore, the capital-output ratio path implies a unique utilization path. TFP net of changes in capital utilization can then be computed as:

$$ z_t^u = \frac{y_t}{(u_t k_t)^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e}}. $$

While no further adjustment to national accounts data is needed to implement those calculations, the capital stock needs to be recalculated, because its evolution depends on utilization in each period. The capital stock and the utilization rate need to be calculated recursively. Using an initial capital stock and a value for parameter ϕ we calculate utilization as defined

by condition (4.4). Then next period's capital stock can be calculated using the following law of motion:

$$k_{t+1}^f = k_t^f \left(1 - \frac{u_t^\phi}{\phi}\right) + i_t$$

where i_t is gross capital formation.[20] Proceeding recursively yields a complete path for capital, utilization and, therefore, TFP adjusted for utilization. Implementing this procedure requires a value for ϕ, the curvature of the depreciation schedule. Simple algebra shows that in this model the steady state depreciation rate is equal to $\frac{r}{\phi-1}$. We choose ϕ to imply a steady state yearly depreciation rate of 8% (the constant depreciation rate we assumed in the benchmark model), assuming that interest rates eventually become constant at their last value in our sample.

Figure **??** shows the behavior of capital utilization between 1991 and 2003, and the resulting adjusted TFP path. Because our measure of the capital-output ratio falls in 1995, utilization does as well. This makes intuitive sense. TFP in the first quarter of 1995 falls by a large amount while interest rates (the opportunity cost of capital) increase significantly. This gives firms an incentive to postpone the consumption of capital services. Specifically, we find that utilization fell 5.7% between the last quarter of 1994 and the last quarter of 1995. This implies that adjusted TFP falls less than unadjusted TFP (5.1% versus 7.1%). Note however that it continues to fall by a large amount. In fact, relative to movements outside of the crisis period, the 1995 change in adjusted TFP is as much of an outlier as the change in unadjusted TFP.

The key question is whether making capital utilization endogenous improves the ability of the model to account for the behavior of output and input use during the crisis. To answer that question, we first recalibrated parameters to continue matching our calibration targets. Figure **??** plots the predictions of the model for GDP, labor, capital and energy, in the perfect foresight and perfect surprise experiments.

[Figure 8: results from model with variable capital utilization]

The results are quantitatively similar to those we obtained in the benchmark model. GDP, labor, and capital fall much more than in the data. In fact, the model with utilization

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[20]Data on gross capital formation has been adjusted so that it corresponds to the empirical counterpart of theoretical gross investment in this model.

predicts falls in all variables that are of magnitude similar to the ones we found in the benchmark model. This is the case even though adjusted TFP falls less than unadjusted TFP. The reason for this is simple: utilization is a new margin of adjustment when shocks hit the economy. When faced with an exogenous shock in this model, firms can adjust labor and energy use as before, but they can also change utilization rates. This is reminiscent of the results in Burnside and Eichenbaum (1996). They show that the response of the economy to a given productivity shock is magnified once variable capital utilization is introduced into a real business cycle model. The predicted fall in utilization in 1995 is 8.1% in the PF experiment and 8% in the PF one. This is higher than in the data because the model predicts a greater increase in the capital output ratio than observed.

In summary, including variable capital utilization helps account for some of the variance of TFP but does not improve the performance of the model during 1995. The model predicts that utilization and hours should fall by a counterfactually large amount in relative terms 1995, as should, therefore, output.

We also carry out experiments with different values of ϕ. Recall that this parameter determines the elasticity of depreciation with respect to utilization. We experimented with various values for ϕ, including a value such that the implied steady state depreciation rate is 5% on a yearly basis. The quantitative results remained practically the same in all cases. Those results are available upon request.

4.4.2 Labor hoarding

We now give firms another margin of adjustment when confronted with exogenous shocks: effort. A drop in unobservable effort in 1995 could explain another part of the fall in unadjusted TFP. Whether this will help the model's performance in terms of output is unclear, as in the case of capital utilization. TFP adjusted for both capital utilization and labor hoarding may fall less than unadjusted TFP, but firms now have two additional margins to reduce output. Nevertheless, introducing labor hoarding should improve the model's predictions for hours. Since firms can now reduce labor use via effort, hours should fall less in 1995.

We model labor hoarding in the spirit of Burnside et al. (1993). Time devoted to work by household is indivisible: employed households devote time $f > 0$ to work while

unemployed households devote no time to work. As in Hansen (1985) and Rogerson (1988), we convexify the choice set of households by allowing them to randomize between employment and unemployment. Specifically, households choose a probability l_t of working in a given period, a level c_t^e of consumption when employed, a level c_t^u of consumption when unemployed, and a level ϵ_t of work effort when employed. We further assume that working entails a fixed cost $\kappa > 0$. Household maximize:

$$\sum_{t=0}^{+\infty} \beta^t \left[l_t \log \left(c_t^e - \kappa - \frac{1}{\nu} (f\epsilon_t)^\nu \right) + (1 - l_t) \log (c_t^u) \right].$$

With this utility function, effort is independent of consumption and income, as labor supply was in the benchmark model. This makes the model with labor hoarding comparable to the benchmark model in the sense that the wage elasticity of aggregate labor supply is governed by exogenous parameter $\nu > 1$, and, in particular independent of income and consumption. We assume as Burnside et al. that adjusting labor between periods is costly, although our specification of the cost is different from theirs. Without adjustment costs, one easily shows that the optimal level of effort is constant across periods. Burnside et al. assume that it takes a quarter to adjust employment. Given our modeling of expectations, this constraint would never bind in our model. We assume instead households who change their work probability from l_t to l_{t+1} in period $t + 1$ bear costs $\frac{\psi_l}{2} (l_{t+1} - l_t)^2$ where $\psi_l > 0$. This specification is similar to the one used by Cogley and Nason (1995). As in the case for capital in the benchmark model, assuming that adjustment costs are borne by households rather than by firms is immaterial but simplifies the exposition by keeping the firm's problem static. Letting w_t be the price of labor services, households now face budget constraint:

$$(l_t c_t^e + (1 - l_t) c_t^u) (1 + \tau_t^c) + k_{t+1} + a_{t+1}$$

$$= l_t \epsilon_t w_t \left(1 - \tau_t^l \right) + a_t(1 + r_t \left(1 - \tau_t^k \right)) + k_t(1 + r_t^k \left(1 - \tau_t^k \right)) - \frac{\psi}{2} (k_{t+1} - k_t)^2 - \frac{\psi_l}{2} (l_{t+1} - l_t)^2.$$

In Hansen (1985) or Rogerson (1988), it is optimal for agents to equate consumption across employment states. In our model this is not the case. It remains true that households equate

utility across employment states at all dates t:

$$c_t^e - \kappa - \frac{1}{\nu}(f\epsilon_t)^\nu = c_t^u. \tag{4.5}$$

But this implies that employed households consume more than unemployed households, when in Hansen (1985) or Rogerson (1988) an household's consumption is independent of their employment status.

Output at date t is now defined by

$$y_t = z_t^{u,e} \left(u_t k_t^f\right)^{\alpha_k} (n_t f\epsilon_t)^{\alpha_n} e_t^{\alpha_e},$$

where ϵ_t is the firm's effort choice. Variable n_t is the fraction of households that the firm employs. In equilibrium, n_t must equal l_t in all periods.

We now turn to calculating TFP adjusted for both capital utilization and effort. Capital utilization satisfies the same condition as in the previous model. But we need an expression for effort as a function of observable time-series: capital, labor and output. From first order conditions, we obtain:

$$\epsilon_t = \left(\frac{\alpha_n(1-\tau_t^l)y_t}{f(1+\tau_t^c)n_t}\right)^{\frac{1}{\nu}}. \tag{4.6}$$

Note that effort depends negatively on both the tax on labor and the tax on consumption. Calibrating ν is difficult since independent evidence on this parameter is not available. We begin by setting $\nu = 1.5$, the value we used for the curvature of the disutility of labor in the benchmark model. Given the lack of evidence on this parameter, we will make sure via sensitivity analysis that our results do not critically depend on the value we picked. The fixed length of work f is set to 0.45. This number corresponds to average hours per worker from 1987 to 1994, relative to discretionary time available in a quarter, 1300 hours.

Having measured effort and capital utilization, adjusted TFP at date t is given by:

$$z_t^{u,e} = \frac{y_t}{(u_t k_t)^{\alpha_k} (n_t f\epsilon_t)^{\alpha_n} e_t^{\alpha_e}}.$$

Figure **??** shows that TFP adjusted for effort and capital utilization varies very little com-

pared to unadjusted TFP and TFP adjusted for capital utilization. In other words, effort and utilization together account for a large part of measured movements in TFP. Although small in absolute terms however, the 1995 fall in adjusted TFP is unusually large relative to the behavior of the series outside of the crisis. It is, as in the benchmark economy, an outlier. We also found that when ν is raised, effort becomes inelastic and the percentage fall in TFP adjusted for capital utilization and in TFP adjusted for utilization and effort become very similar. TFP movements become smaller if ν is close to one.

[Figure 9: Comparing TFP measured with benchmark model, model with capital utilization, and model with capital utilization and effort]

The key question we want to ask is whether correcting for effort helps the model's performance during the crisis. In order to simulate the model in this case, we need to assign values to a few more parameters. In all experiments we choose κ to match the average level of employment before the crisis. As before, ψ_k is chosen to match the volatility of the investment to GDP ratio before the crisis. The natural way to calibrate the labor adjustment cost parameter, ψ_l, is to try and match the standard deviation of employment before the crisis. But as a result of the size of the shocks in 1995, we find that matching this statistics was not possible. As we explain below, the evolution of labor in this model, like the evolution of capital, is governed by a second order difference equation. Labor does not remain between reasonable bounds for some parameters. We found that keeping employment swings reasonable required choosing a value for ψ_l that implies counterfactually little variation in hours before the crisis. Also to keep employment swings within reasonable bounds, we computed the model under optimistic expectations for the interest rate, expectations such that the model matches the behavior of the capital-output ratio before the crisis. Because labor adjustment costs are calibrated in this fashion, the predictions of this version of the model cannot be compared directly to our previous results. We view then as an illustration of the potential ability of labor hoarding to explain the behavior of output during the crisis.

Computing the model is now more challenging. It requires solving for the stable path of two simultaneous second order difference equations: one for capital and one for labor. To

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see this not that utility maximization by households implies that labor solves:

$$c_t^e - c_t^u - \psi_n(n_{t+1} - n_t) + \epsilon_t w_t(1 - \tau_t^l) + \psi_n(1 + r_{t+1}(1 - \tau_{t+1}^k))(n_{t+2} - n_{t+1}) = 0 \quad (4.7)$$

To obtain a second order difference equation for labor that does not involve w_t, we need to consider the firm's problem. At a solution, the price of labor services equals its marginal product:

$$w_t = \frac{\alpha_n y_t}{\epsilon_t n_t}. \tag{4.8}$$

Manipulating (**??-??**) yields the following conditions on the evolution of labor:

$$n_{t+2} = n_{t+1} + \frac{1 - \tau_t^l}{\psi_n}\left(\alpha_n\left(1 - \frac{1}{\nu}\right)\frac{y_{t+1}}{n_{t+1}}\right) - (n_{t+1} - n_t)(1 + r_{t+1}(1 - \tau_t^k)) \tag{4.9}$$

The evolution of capital remains governed by the same second order equation as in the previous model. Equation (**??**) enables us to infer a path for effort from the evolution of the output (y_t) to hours worked per capita ($n_t f$) ratio, provided values for exogenous parameters have been chosen. The algorithm we use to compute stable labor and capital path given exogenous parameters is in appendix B.

The predictions of the model expectations are shown in figure **??**. Hours worked become very smooth, like capital, which is not surprising since their evolution is governed by a similar second order difference equation, and labor adjustment costs are set high. In particular, hours worked now fall very little in 1995. But effort falls markedly once the crisis hits as agents adjust their expectations. Because hours fall very little, GDP falls much less than before during the crisis. But over time, as labor slowly adjusts GDP falls markedly below its data counterpart and eventually diverges from it by magnitudes quite similar to what we obtained in the benchmark economy. As in the model with capital utilization only, GDP falls a lot even though adjusted TFP does not because firms make use of a new margin of adjustment: effort. The fall in adjusted TFP, while small in absolute terms, is unusual in relative terms, and it has a big impact on effort as a result. Labor hoarding appears to account for big chunk of TFP movements during the crisis, but the model continues to overpredict the fall in output that results from the 1995 TFP shock. We also experimented with various values

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for ν. As ν falls, effort becomes more elastic and the impact of the crisis on TFP becomes smaller, while the opposite is true when ν rises.

5   Conclusion

Some preliminary results are the following. Benchmark model: output, and inputs, fall twice as much as observed, in percentage terms. The source of this large fall is the collapse of TFP. Changes in fiscal policy have a much smaller impact. This result is robust to matching the path for capital before the crisis. Also, we can find a value for the elasticity of labor such that we match the fall in output. But then labor varies much less than in the data. The main result is robust to using logarithmic preferences, which do not eliminate income effects. The results remain the same in the model with variable capital utilization. The introduction of labor hoarding reconciles the fall in TFP with the magnitude of the fall in output. However, the behavior of predicted employment is very different from the observed one.

A   Data for benchmark model

To construct a capital stock series consistent with the model, we use private and public gross capital formation and purchases of durable goods. We construct a stock series for each kind of investment, using the perpetual inventory method.[21] To construct the stock of private capital, we assume a yearly depreciation rate of 6%. To construct the stock of government capital, we assume a depreciation rate of 5%. To construct the stock of durable goods, we assume a depreciation rate of 20%. To construct total investment, we add up total gross capital formation and purchases of durable goods. To construct the stock of total capital, we add up the three previous stocks. The average yearly depreciation rate implied by the total stock of capital, total investment and the law of motion of capital is 8%, which is of similar magnitude to the one usually found through calibration of the neoclassical growth model to the US economy.[22] As mentioned previously, we impute the return to government capital and to the stock of durable goods and add it to measured GDP. We assume a yearly

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[21]Gross capital formation data includes the empirical counterpart of theoretical adjustment costs. We assume these costs are small and treat all investment as contributing to the capital stock. Mendoza (1991) reports that the empirical magnitude of adjustment costs in capital for the U.S. is equal to 0.1% of GDP. Our model predicts in all cases that adjustment costs do not exceed 0.5% of output on average.

[22]Kydland and Prescott (1982) report a yearly depreciation rate of 10%. Cooley and Prescott (1995) report a yearly depreciation rate of 5%.

return of 4%. This is the return of inflation-indexed U.S. government bonds reported in McGrattan and Prescott (2000). We also impute depreciation from durable goods and add it to measured GDP.

B   Computational appendix

Benchmark model

Simple manipulations of first-order conditions for profit maximization show that output can be reduced to a function of capital, so that equation (**??**) is a second order difference equation for capital only. We assume that all exogenous variables stay at their 2003Q1 for ever. Given k_0, we look for the unique k_1 so that the economy eventually converges to steady state via a standard shooting algorithm. All endogenous variables can then be calculated as a function of the path of physical capital. In the perfect foresight experiment, the algorithm is re-started in the first quarter of 1995 using as initial value for capital the value agents would choose under the assumptions that all variables remain at their average pre-crisis level for ever.

Standard preferences

Given parameter values and paths for exogenous shocks, the algorithm we use consists of the following steps:

1. Set an initial level $\frac{c_0}{y_0}$ for the consumption output ratio. Find n_0 from (4.3) given that $y_0 = z_0 k_0^{\alpha_k} n_0^{\alpha_n} e_0^{\alpha_e}$, that n_0 and k_0 are known, and that, from first order conditions of the firm, $e_0 = \alpha_e \frac{y_0}{p_0^e}$.

2. Get c_1 from (4.1).

3. Guess k_1 and get y_1 and n_1 using (4.3) and the definition of output.

4. For $t \geq 0$ obtain c_{t+2} and k_{t+2} sequentially using (4.1-4.3) and the difference equation on capital

5. Iterate on k_1 until path for capital is stable (i.e. variables converge to steady state values).

Having obtained a path for all endogenous variables save assets, we simply find the unique a_0 so that the asset path implied by the household's budget constraint is stable.

Capital utilization

Utilization is a function of the capital-output ratio. Therefore, (**??**) can be written as a second order difference equation for capital only as in the benchmark model, and the same shooting algorithm can be used.

Labor hoarding

The algorithm we use in the Labor hoarding is as follows, given initial values (k_0, n_0) for capital and labor set to their data counterparts:

1. Guess a full path $\{n_t^{guess}\}_{t=0}^T$, where T is a large number, for employment.

2. Choose k_1 so that, given the labor guess, the path predicted by the second order difference equation for capital is stable.

3. Find n_1 so that given the path for capital obtained in step 2, the path for labor predicted by (**??**) is stable.

4. Iterate until the paths for labor and capital are approximately invariant

In the perfect foresight experiment, the algorithm is re-started in the first quarter of 1995 using as initial value for capital and employment the values agents would choose under the assumptions that all variables remain at their average pre-crisis level for ever.

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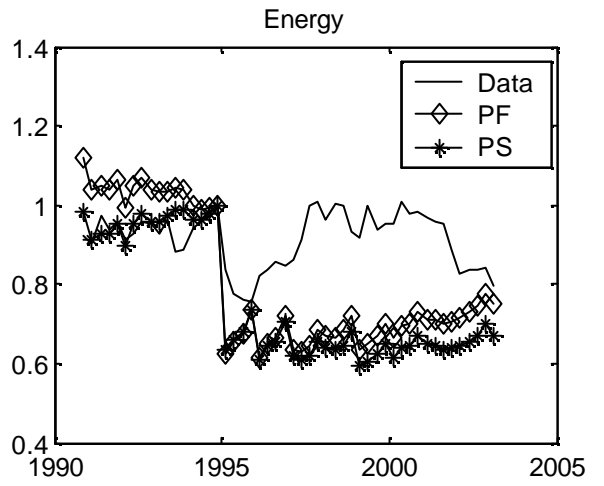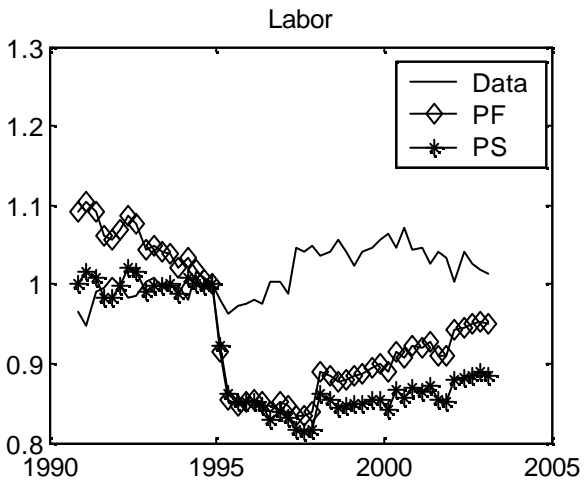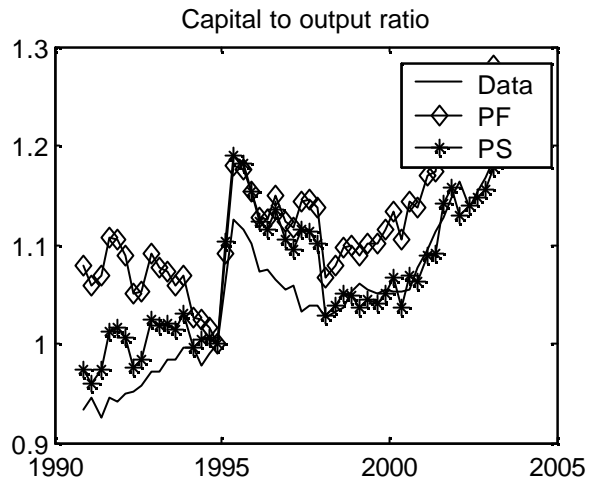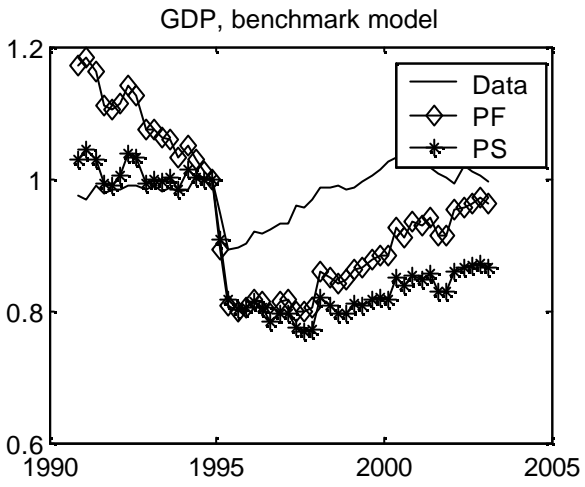   Benchmark total factor productivity
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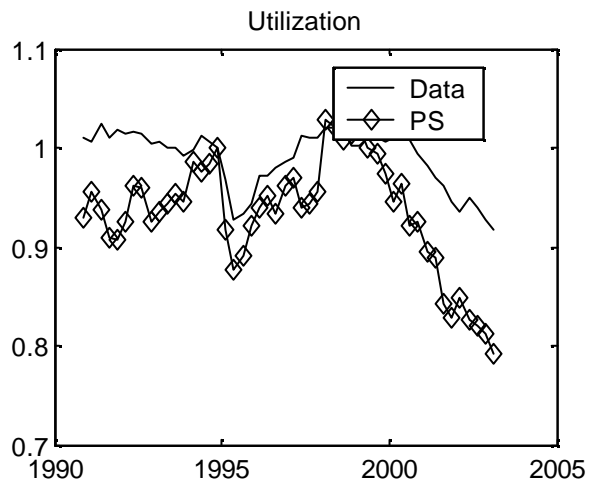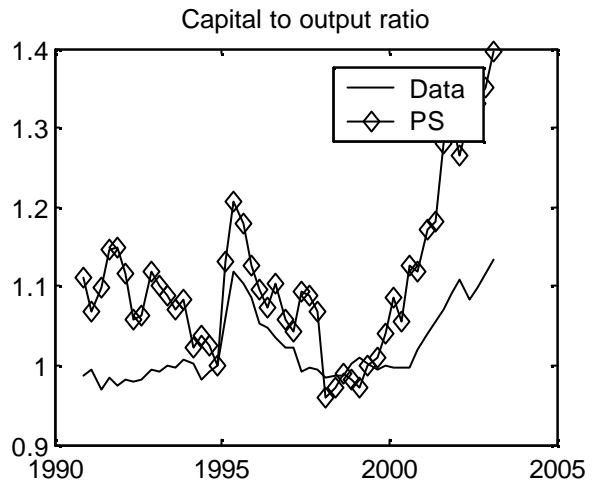
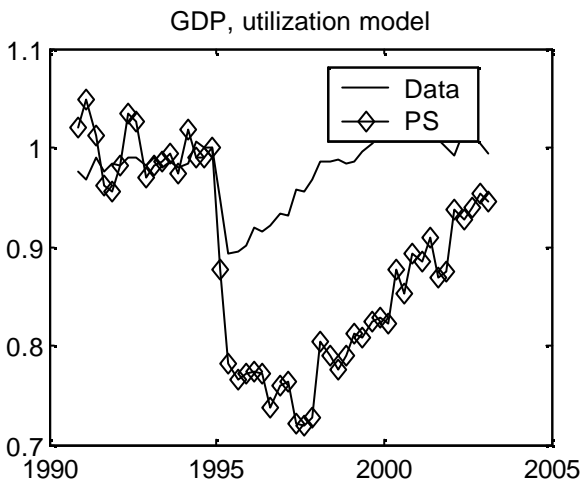

Labor

GDP, utilization model

Capital to output ratio

Labor

Utilization

Total Factor Productivities, 1994.4=1

GDP, LH model
Capital to output ratio
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Energy
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