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Factor Utilization and the Real Impact of Financial Crises

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Abstract

Total factor productivity (TFP) falls markedly during financial crises, as we document with recent evidence from Latin America and Asia. We study the ability of various versions of the small open economy neoclassical growth model to account for the behavior of inputs, output, and aggregate productivity during Mexico's 1994-95 crisis. We find that that capital utilization and labor hoarding can account for a large fraction of the fall in measured productivity. While capital utilization alone does little to improve the performance of the model during the crisis, introducing labor hoarding significantly reduces the gap between the evidence and the predicted fall in output and hours.

KEYWORDS: Financial crises, Total factor productivity, Quantitative analysis

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1 Introduction

Output falls drastically following financial crises, typically much more than measured capital and hours. Correspondingly, standard growth accounting suggests that total factor productivity (TFP) collapses during financial crises, as we document with recent evidence from Latin America and East Asia. The magnitude of these drops presents a challenge for growth models driven by exogenous TFP shocks. Given the behavior of productivity, these models predict that input use, hence output, should fall much more than they typically do in the data.

Our goals in this paper are to document the unusual behavior of TFP during crises, and to study potential explanations for this behavior and the associated contraction in output. Specifically, we use evidence from Mexico's 1994-95 "Tequila" crisis to argue that factor utilization can account for a significant part of the fall of conventionally-measured TFP during financial collapses. We find that augmenting the standard open economy neoclassical model to allow for endogenous factor utilization yields much improved predictions for the behavior of output and inputs during the crisis. Furthermore, whereas the TFP drop plays a dominant role in the model with fixed utilization, fiscal and interest rate shocks account for a significant part of the output contraction in a model with endogenous capital utilization and labor hoarding. In other words, we find that changes in factor utilization magnify the effects of non-technological shocks, leaving much less for exogenous productivity movements to explain.

Intuitively, one should expect large swings in capital utilization and effort during crises. For several quarters, interest rates are well above average, while TFP 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, if employment is costly to adjust, firms may use the effort margin to respond to the fall in the marginal product of labor.

We find, in fact, that standard models of factor utilization (as in Greenwood, Hercowitz and Huffman, 1988, and Burnside, Eichenbaum and Rebelo, 1993) can account for most of the variance of conventionally-measured TFP both during and outside the crisis period in Mexico.

Introducing capital utilization yields a smaller decline in TFP as reduced utilization accounts for some of the fall in output. However, when fed into a growth model augmented to include variable capital utilization, the response of utilization amplifies the effect of the adjusted TFP shock. In combination, the adjusted productivity drop and the utilization fall continue to produce a counterfactually large fall in hours worked, hence in output.

On the other hand, we find that models where both capital utilization and labor hoarding are endogenous predict noticeably smaller falls in output and hours. This suggests that labor hoarding could account for much of the behavior of hours during many financial crises.

Much of the existing literature focuses on what triggers a financial crisis in the first place. For instance, in the case of Mexico's 1994-95 "Tequila" crisis, Flood, Garber, and Kramer (1996) and Calvo and Mendoza (1996) study the role played by financial imbalances (liquid financial assets vs. broad monetary aggregates, and short-run debt vs. gross foreign reserves). 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 a self-fulfilling debt crisis.

These and many related articles have shed light on what causes financial collapses in nations like Mexico, but they do not try to account for the behavior of output after the collapse. Like Calvo (2000) and despite some exceptions which we review below, our assessment is that there has been little emphasis on the deep consequences of crises on real activity. This paper contributes to filling this gap.

Our calculations complement some related investigations of the real impact of financial crises by stressing the importance of TFP, whose unusual behavior most existing studies ignore.[1] Among the exceptions, Gertler, Gilchrist and Natalucci (2003) simulate the impact of shocks to a country's risk premium in a model with price-stickiness and endogenous capital utilization. Their model can predict a fall in output in South Korea of a magnitude similar to the one observed. However, their quantitative analysis assumes that TFP corrected for changes in capital utilization remains constant during the crisis. We calculate in the next section that capital utilization (as Gertler et al. model it) accounts

[1]Burnside, Eichenbaum and Rebelo (2001), Corsetti, Pesenti and Roubini (1999) and Lahiri and Vegh (2005) provide qualitative explanations for the contraction of output. Cavallo, Kisselev, Perri and Roubini (2004) show that large falls in output are possible after crises in sticky-price models with a margin constraint. Similarly, Cook and Devereux (2005) simulate recent crises in Malaysia, South Korea and Thailand and show that output can drop sharply following shocks to a country's risk premium. All these papers assume that TFP is constant. Mendoza (2002) shows that a flexible-price model with a liquidity constraint can lead to sudden stops of capital flows and large output falls. He allows for TFP fluctuations, but only of average business cycle size: the standard deviation of TFP fluctuations coincides with that of output. Chari, Kehoe and McGrattan (2005) show that sudden stops of capital flows induce an output increase, not a fall, in a standard neoclassical model. They argue that more research is needed to find a "friction" that can overwhelm the positive effect of a sudden stop. Our results suggest that explicitly modeling and measuring TFP should suffice.

for less than 40% of the fall of measured TFP in Argentina after the Tequila crisis, and in Indonesia, South Korea and Thailand after the 1997 crisis. In the Mexican case, capital utilization accounts for less than 30% of the fall in TFP in 1995.

Otsu (2006) replicates our exercise with data from South Korea and confirms that conventionally-measured TFP fell by an unusual amount during the 1997 crisis. Unlike us however, he finds that the open economy neoclassical growth model makes predictions for output that closely resemble the evidence. This is not surprising: as we explain in this paper, South Korea's 1997 crisis is one episode where hours fell markedly. The evidence we present in this paper suggests however that many recent crisis episodes do not follow such a pattern.

In the specific case of Mexico's Tequila crisis, Aguiar and Gopinath (2007) propose a process for TFP that allows for a stochastic trend. They do not compare the predicted path of GDP to data. Mendoza (2005) uses a model with financial frictions to nest crisis episodes within business cycles. He reports a large fall in TFP in Mexico in 1995, and attributes parts of it to a fall in intermediate input use. However, he does not ask whether the effect of the TFP shock on output and labor in his model is consistent with the evidence.

Finally, Kehoe and Ruhl (2007) argue that given the mechanics of national accounting, changes in the terms of trade cannot generate large swings in TFP (as customarily measured and as we measure it in this paper). While terms of trade shocks clearly affect a nation's income, the fact that conventionally-measured TFP falls markedly is evidence that productivity falls during crises for other reasons.

Overall, our findings strongly suggest that quantitative studies of the real impact of financial crises should take the unusual behavior of TFP into account, and that factor utilization could account for a significant fraction of the precipitous fall in conventionally-measured productivity and output that follows crises episodes.

2 Evidence

In this section we document the fact that financial crises are often followed by unusually large falls in TFP and GDP using evidence from Mexico's and Argentina's 1994 Tequila crises, Argentina's 2001 crisis, and from the 1997 crises in Indonesia, South Korea and Thailand. In addition, we find that these falls tend to be persistent. Both GDP per capita and TFP usually 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 that A_t, aggregate TFP at date t, equals $z_t(1+\gamma)^{t(1-\alpha)}$, where z_t is stationary and $\gamma \geq 0$ is an exogenous growth rate.

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

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

Measuring z_t requires empirical counterparts for $\widehat{y}_t, \widehat{k}_t$ and l_t. We construct capital stock series using the perpetual inventory approach with geometric depreciation and yearly data from the International Financial Statistics (IFS) database (IMF, 2004).[2] The IFS database reports nominal data on investment. Like Bergoeing, Kehoe, Kehoe and Soto (2002) we measure real investment as the ratio of nominal gross fixed capital formation to nominal GDP multiplied by real GDP. We assume that capital depreciates at a yearly rate of 8%. To set the initial capital stock, we follow Young (1995) and assume that the growth rate of investment in the first five years of the series is representative of the growth of investment in previous years.

As for the labor input, for Mexico we use total hours worked as measured in Bergoeing et al. (2002). They report the product of total employment and average hours per worker in the manufacturing sector, measured with data from a manufacturing sector survey.[3]

Since no hours data are available for all sectors on a quarterly basis for the time period we study in Mexico, a potential concern is that the fall in average hours worked in manufacturing may understate its economy-wide counterpart. However, manufacturing GDP and total GDP behave very similarly in Mexico in 1995. Both variables fell by 8% or more in the second and third quarters of 1995, on a yearly basis. The behavior of employment also suggests that the manufacturing sector did not outperform the rest of the economy during the

[2] In the case of Argentina, we use data for investment, GDP, and hours worked constructed by Kehoe (2003).

[3] We discuss a possible alternative in a detailed data and computational appendix we make available at http://www.dallasfed.org/research/vita/quintin/0704comp.pdf.

crisis.[4] Manufacturing employment fell by almost 8% in 1995. For countries other than Mexico, an estimate of average hours worked is available for most sectors.[5]

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.[6] Detrended variables $\widehat{y_t}$ and $\widehat{k_t}$ are y_t and k_t divided by the average geometric growth factor of y_t in the period before the crisis episode. This factor is 1.0% for Argentina and 1.7% for Mexico between 1960 and 1994,[7] and 3.5% for Indonesia, 5.3% for South Korea, and 4.4% for Thailand between 1960 and 1997.

Finally, we set $\alpha = 0.3$. 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 in a fairly narrow interval around 70%.

Figure 1 shows the resulting series for Argentina, Indonesia, Mexico, Thailand and South Korea with vertical lines marking the onset of each crisis. Each time series is scaled by its respective value at the onset of the crisis.[8] Detrended output falls by 10% or more in most cases during the year following the crisis, with the sole exception of Argentina in 1995 where the contraction was milder.[9] Capital, on the other hand, remains practically constant after the crisis, and hours fall less than output in all cases except, once again, for Argentina's Tequila crisis.

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[4] Manufacturing employment data are available from Mexico's national statistical institute (INEGI).

[5] 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 of age 15 and higher in all sectors. Average hours worked are for all industries, excluding agricultural activities. Data were downloaded from http://www.nso.go.kr. For Thailand, total employment corresponds to employed individuals of age 13 and higher in all sectors, as reported by the International Labour Office (ILO) and the Thai National Statistical Office. Average hours worked correspond to all industries, excluding agricultural activities and public administration, as reported by the ILO. Data were downloaded from http://www.nso.go.th and http://laborsta.ilo.org. For Indonesia, data on hours worked come from http://cippad.usc.edu/ai/.

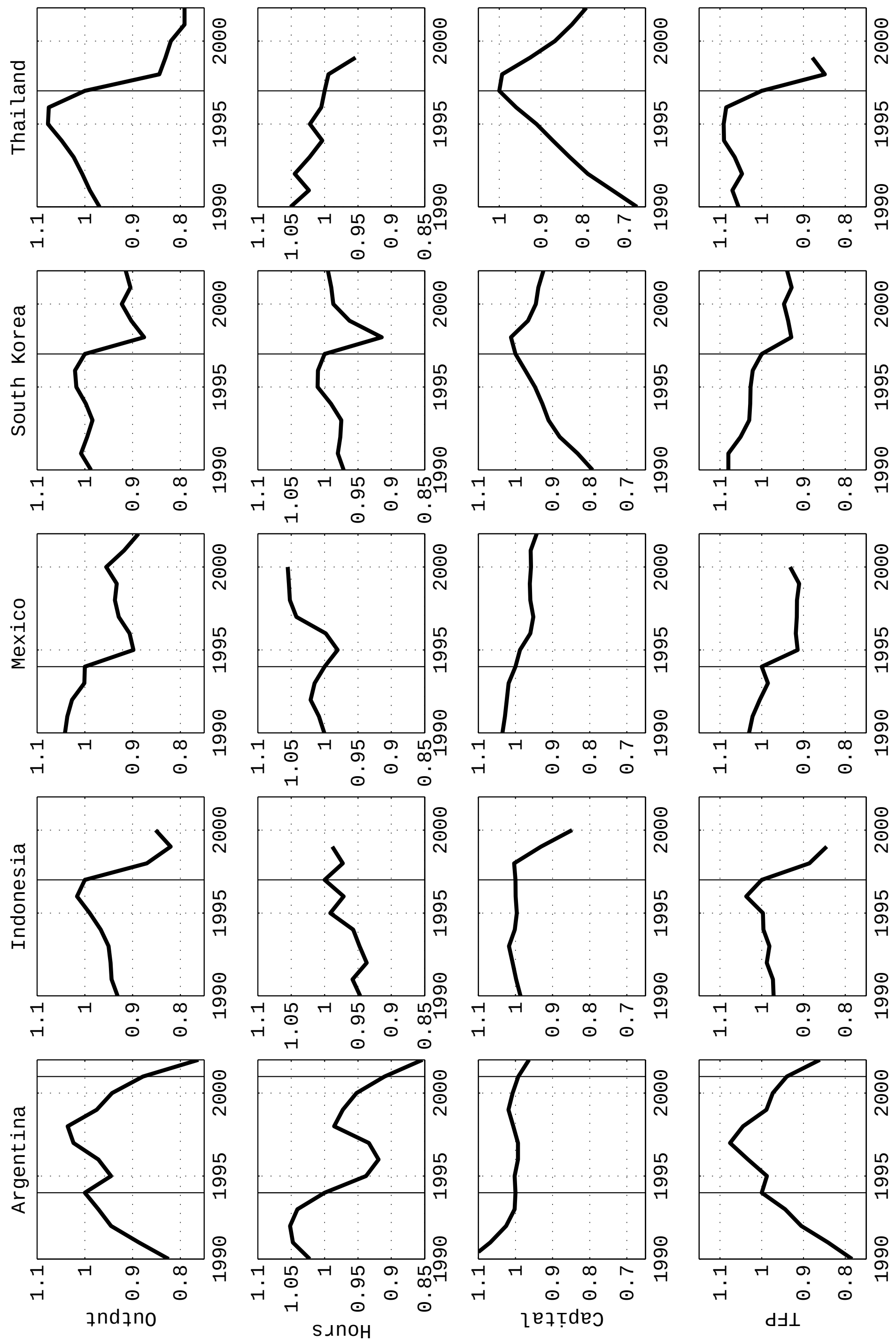
[6] We use population data for Argentina from Kehoe (2003). Indonesia and Thailand data are from the World Bank Development Indicators database (World Bank, 2004). For Mexico we use data reported by Bergoeing et al. (2002). For South Korea, data are from http://www.nso.go.kr.

[7] In the case of Argentina, we use World Bank data to compute the trend growth rate between 1960 in 1994 since data from Kehoe (1993) only start in 1970.

[8] In Argentina's case, we normalize all series to be one in 1994.

[9] In the case of Indonesia, GDP per capita fell by 15%, while GDP per capita excluding Indirect Business Taxes (IBT) fell 10%. We plot numbers that exclude IBT. This is the only country in our sample where the treatment of IBT makes a big difference.

Figure 1: Detrended output, inputs and TFP during recent financial crises



In Mexico, Thailand, and Indonesia hours fall very little following the crisis. During both of Argentina's crisis and South Korea's, hours fall more markedly. In fact, these are the three episodes in our sample where hours seem to behave much in the way the standard neoclassical model would predict. Not surprisingly then, Otsu (2006) finds that the model makes reasonable predictions for the behavior of output and labor in the aftermath of the Korean crisis. We show in this paper that crises where measured hours behave as they did in the case of Mexico's Tequila crisis present a greater challenge for neoclassical models.

Since capital and labor fall relatively little during crises in most cases, TFP has to fall by a large amount to account for the fall in output: 7.9% in Argentina in 2002, 11.4% in Indonesia, 8.6% in Mexico, 15.1% in Thailand, and 7.1% in South Korea. The magnitude of these falls is quite unusual for all countries. Argentina's response to the Tequila crisis in 1994 is once again somewhat of an exception, but notice that TFP was on a steeply upward trend before the crisis, and that it suddenly stopped growing in 1995.

Also notice that the falls in output and TFP triggered by crises tend to be persistent. They remain below trend in most cases for several years. Like us, Cook and Devereux (2005) find that output remains persistently below trend in Asia after 1997, using a different detrending procedure. They report that in Malaysia, South Korea and Thailand, output remains below trend for at least 8 quarters.

Naturally, these results could be sensitive to some of our measurement assumptions. Young (1995) argues for instance that data on changes in inventories are of poor quality in East Asia. Excluding changes in inventories from our calculations had small consequences on our results.[10]

Changing $(1+\gamma)$ to 1.02 for all countries, the value Kehoe and Prescott (2002) propose, also has little effect on results, with one exception.[11] In the case of South Korea, the effect of the 1997-98 crisis becomes less persistent as

[10]Our TFP findings for South Korea can be compared to results in Young (1995). He reports that the average logarithmic annual growth rate of A_t in South Korea was 1.7% between 1966 and 1990. Using his numbers, the growth rate between 1970 and 1990 is 1.8%. The main difference between his calculations and ours is that he takes into account changes in the quality of labor and capital. After excluding inventory changes as he does, we calculate that the average logarithmic annual growth rate of A_t for South Korea for the period 1970-1990 is 2.6%. The difference is large and is due to the adjustment for quality. Assuming a labor income share of 70% and using results in Young (1995) on the growth of *raw inputs*, we find that A_t in South Korea grew at an average rate of 2.7% between 1970 and 1990.

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

$\widehat{y}_t$ and z_t surpass their 1997 levels by 2000.

Next, one can carry out all calculations using national sources of data for $\widehat{y}_t$ and $\widehat{k}_t$ instead of IMF data. National Income and Product Account series are usually much shorter because countries modify their systems of national accounts every now and again, which makes results more sensitive to the choice of initial capital. On the other hand, IMF data include only the most basic national accounts variables. Data from national sources are richer and allow one to construct more accurate empirical counterparts of theoretical variables, as we do in the next section. In particular, one can subtract indirect business taxes from GDP, impute the returns of government capital and of the stock of durable goods, and include public investment and durable goods purchases in investment (with different rates of depreciation for each type of capital.) After making those corrections, 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 tend to be unusually large.[12]

The fact that measured inputs fall relatively little during crises suggests that factor utilization could explain some of the behavior of TFP and output. We discuss this possibility at length in the case of Mexico in the remainder of this paper. Using a small open economy version of the capital utilization model of Greenwood, Hercowitz and Huffman (1988) and calibrating parameters such that the steady state depreciation is 8%, we find that capital utilization can account for 25%, 38%, 36% and 17% of the fall of measured TFP in Argentina in 2002, and in 1998 in Indonesia, South Korea and Thailand, respectively.[13]

In summary, financial crises trigger unusually large falls in detrended GDP per capita and conventionally-measured TFP. There is also some evidence that these falls are persistent. The remainder of the paper studies the ability of various versions of the small open economy neoclassical growth model to account for the behavior of output and inputs during Mexico's Tequila crisis.

[12]We carried out these calculations for Mexico, South Korea and Thailand. Mexican data were downloaded from http://dgcnesyp.inegi.gob.mx. South Korean data were downloaded from http://www.nso.go.kr. Thai data were downloaded from http://www.nso.go.th. Carrying out these adjustments can have important consequences for some countries where financial crises took place, as mentioned in a previous footnote on the role of IBT in Indonesia. These adjustments make data consistent with variables in the simplest growth model. See Cooley and Prescott (1995).

[13]We set the parameter of curvature of the depreciation function to 1.5 which, assuming long-run international real interest rates of 4%, implies a steady state rate of depreciation of 8%.

3 The small open economy neoclassical model

We begin by evaluating the consistency of the standard small open economy neoclassical model with the behavior of output and inputs after Mexico's Tequila crisis. We model the crisis as exogenous shocks to TFP and interest rates. Feeding these shocks into the model yields paths for endogenous variables that we compare to data. We will then argue that introducing factor utilization into the standard model helps account for the behavior of TFP, inputs and outputs during the crisis.

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. Incorporating these elements will enable us to measure the quantitative impact of fiscal shocks on the behavior of output in Mexico in 1995. However, this complicates computations by preventing us from solving a standard planner's problem.

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.[14]

With this utility function, labor supply depends only on the current wage, w_t, and is independent of consumption or income. This function is commonly used in small open economy models (see e.g. Mendoza 1991, 2002, Correia, Neves and Rebelo, 1995 and Neumeyer and Perri, 2005). Correia, Neves and Rebelo (1995) argue that it improves the ability of small open economy models

[14]The assumption that the wage elasticity of labor supply is constant across periods is a bit strong given that the demographic composition of Mexico's labor force changed somewhat over the time period we consider. However, low-frequency changes in this parameter are unlikely to change results we obtain for the short Tequila crisis period. Furthermore, while we argue below that large changes in ν can have a significant effect on the model's predictions, small changes have little impact on our basic results.

to replicate business cycle regularities.[15]

Households have access to an international capital market where one-period risk-free claims earn exogenous return r_t at date 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

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

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. In addition, households receive transfer T_t from the government. Therefore, letting w_t denote the price of labor, households face the following budget constraint[16] at date t:

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

We also assume that household borrowing is bounded so as to rule out Ponzi schemes, and that the bound is high enough in absolute value to never bind in equilibrium.

At date t, firms transform physical capital $k_t^f \geq 0$, and labor $n_t \geq 0$ into

[15] Correia et al. (1995) and Neumeyer and Perri (2005) point out that this function is not consistent with a balanced growth path, unless the disutility of working increases with the rate of labor-augmenting technological change. In our model, there is no technological change. We follow Greenwood et al. (1988) and compare model predictions to data which have no trend.

[16] Note that $1 + r_t^k$ is the *net* price of physical capital. In other words, letting R_t^k denote the gross rental rate at date t, $r_t^k = R_t^k - \delta$. In terms of this gross rental rate, the capital income portion of household income takes the familiar form $k_t(1 + (R_t^k - \delta)\left(1 - \tau_t^k\right))$ while firms maximize $z_t\left(k_t^f\right)^{\alpha_k} n_t^{\alpha_n} - k_t^f R_t^k - n_t w_t$. Making depreciation explicitly part of the firm's problem makes discussing endogenous utilization (as we do in the next section) easier.

quantity $y_t = z_t \left(k_t^f\right)^{\alpha_k} n_t^{\alpha_n}$ of the consumption good, where $\alpha_n = 1 - \alpha_k \in (0,1)$ and z_t is TFP. Fraction $\delta > 0$ of the physical capital firms purchase from households depreciates within each period. Therefore, firms choose (n_t, k_t^f) to maximize:

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

The government 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 that tax revenues are rebated lump-sum to households. The government's date t budget constraint is:

$$\tau_t^c c_t + \tau_t^l l_t w_t + \tau_t^k \left(a_t r_t + k_t r_t^k\right) = T_t. \tag{1}$$

We can now define an equilibrium under the simplifying assumption that agents perfectly foresee the path of TFP, taxes and the exogenous interest rate. 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 $\left\{w_t, r_t^k\right\}_{t=0}^{+\infty}$, consumption, labor supply and asset sequences $\{c_t, l_t, k_{t+1}, a_{t+1}\}_{t=0}^{+\infty}$, sequences of labor and capital demands $\left\{n_t, k_t^f\right\}_{t=0}^{+\infty}$, and a sequence $\{T_t\}_{t=0}^{+\infty}$ of transfers such that, given prices, 1) $\{c_t, l_t, k_{t+1}, a_{t+1}\}_{t=0}^{+\infty}$ solves the household's problem, 2) $\left\{n_t, k_t^f\right\}_{t=0}^{+\infty}$ solves the firm's problem, 3) the market for physical capital clears ($k_t = k_t^f$ for all t), 4) the labor market clears ($n_t = l_t$ for all t) and 5) transfers satisfy (1).

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

3.2 Data and calibration

Computing the predictions of this benchmark model for Mexico requires paths for exogenous shocks $\{z_t, r_t, \tau_t^c, \tau_t^k, \tau_t^l\}_{t=0}^{+\infty}$ that are consistent with our model. This requires a few adjustments to national income and product accounts data. Date t TFP in the benchmark model is:

$$z_t = \frac{y_t}{k_t^{\alpha_k} n_t^{\alpha_n}}. \tag{2}$$

Therefore, we need empirical counterparts for the theoretical variables y_t, k_t, and n_t. We use quarterly data to construct these counterparts.[17]

[17]See the data appendix for details.

National accounts data are from Mexico's national statistical institute (INEGI). There are two conceptual differences between GDP as reported in the Mexican national accounts and output y_t in a given period t in the model. First, GDP includes indirect business taxes (IBT), whereas output y_t does not. Second, output includes the return to all types of capital in the model, whereas GDP does not. It excludes the return on government capital and the return plus depreciation of the stock of durable goods. We make the corresponding adjustments to GDP to construct a measure of output consistent with our model.

Besides empirical counterparts for y_t, k_t, and n_t, factor shares must be specified before measuring TFP. We assume that the ratio of labor income to GDP is 0.7. This assumption is supported by the work of Gollin (2002), who finds that after 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 then generate a series for TFP using equation (2) in each period.

Turning to exogenous shocks other than TFP, we calculate the 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 (dollar-denominated) 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.[18] Our sample of Mexican Brady bond data starts in the last quarter of 1990 and ends in the first quarter of 2003.

We calculate taxes on consumption, labor income and returns from capital and international assets using the method described by Mendoza, Razin and Tesar (1994).[19] The calculated taxes are average effective tax rates, i.e the

[18]Neumeyer and Perri (2005) use a similar construct to study the relationship between business cycles and international interest rates in developing countries. We use end of quarter rates, using average rates does not alter our quantitative findings.

[19]Only data on total income tax revenues are available in Mexico. We follow the estimate reported in Fernandez and Trigueros (2001) to split total income tax revenue into its components: individual and 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 Mexico, we choose to include it. We are constrained to use yearly data

ratio of tax revenue to the tax base.

Figure 2 plots the measured shocks. 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 1995. Output falls by 9.7% between the last quarter of 1994 and the last quarter of 1995, while capital falls by 1.0% and labor falls by 2.0%. Given these data, conventionally-measured TFP must fall by 8.2% to account for the fall of gross output in 1995.[20]

Interest rates measured in annual terms rise from 8.7% on average during 1994 to 19.5% in the first quarter of 1995. The consumption tax rate 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 income falls from 9.3% to 7.4%.

Overall, the Mexican economy underwent a number of severe shocks in 1995. We will now argue that given the magnitude of these shocks, our benchmark model predicts that output should have fallen much more than it did. We will also argue that the quantitative impact of changes in fiscal policy is small compared to the role of TFP.

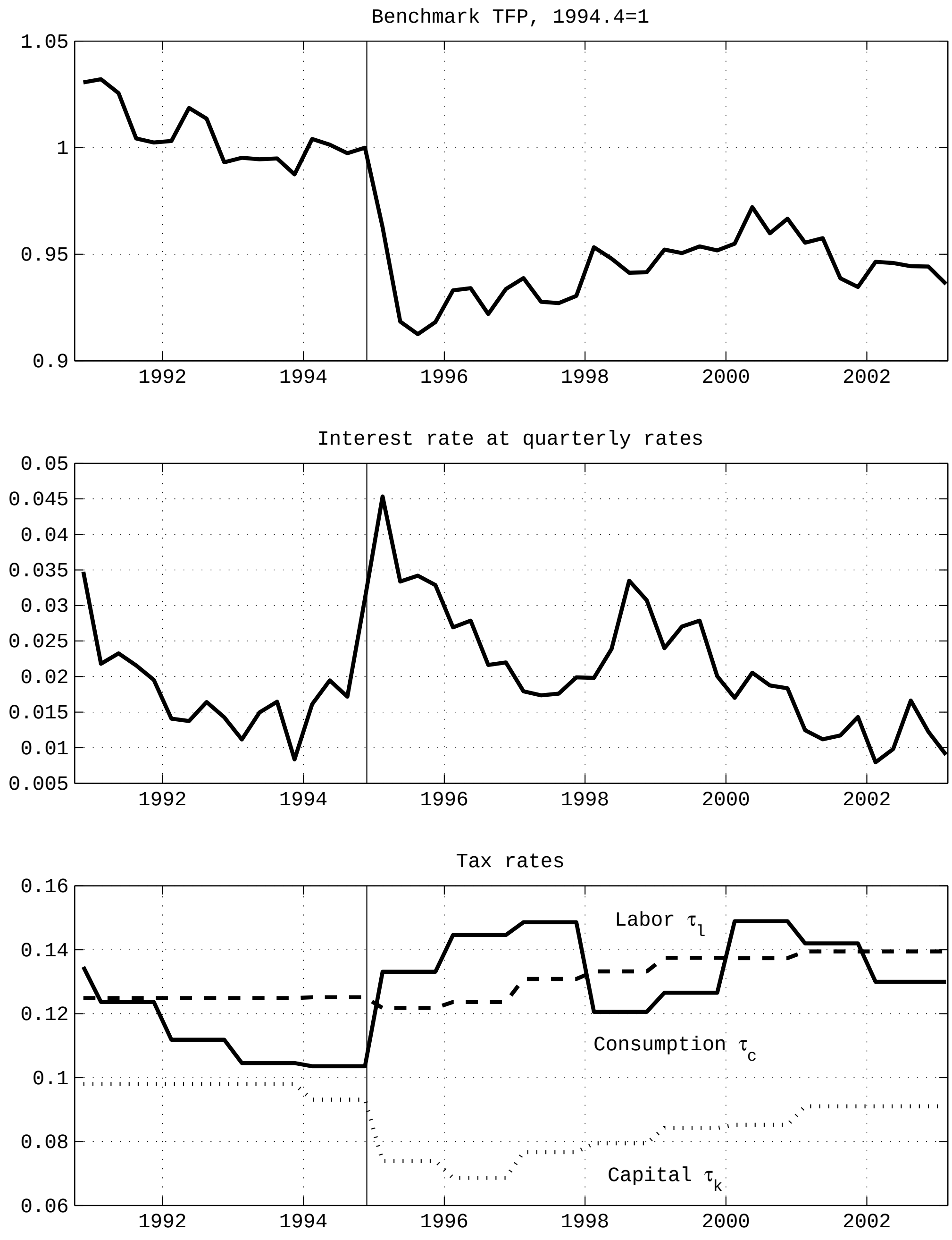
To make these points, we first need to calibrate preference and adjustment cost parameters. One way to calibrate the model would be to assume that at a given date Mexico was on a balanced growth path. However, we do not think that such an assumption is appropriate. Mexico underwent a series of deep crises 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 certain statistical properties of inputs and investment before 1995.

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 person before 1995. As for ν, we begin by setting it to 1.5, which implies a wage elasticity of labor supply of 2, the value used

to measure taxes. We assume in the numerical experiments that taxes remain constant throughout each year.

[20] In a previous version of the paper, we also considered the potential role of energy use. There was a significant fall in energy use in Mexico after 1994, but we calculated that this fall accounts for only a small part of the behavior of TFP during the crisis. Modeling the role of energy use in production made little difference in terms of the predicted path of GDP, labor and capital. This is not surprising since the share of energy expenditures in gross output is small.

Figure 2: Shocks during Mexico's Tequila crisis



in Mendoza (1991).[21] It falls within the range mentioned by Greenwood, Hercowitz and Huffman (1988), who cite studies of labor supply in the United States. We were unable to find similar studies for Mexico. The next section provides some sensitivity analysis on this key parameter.

The value of the discount rate does not directly affect the predicted path for input and output series in the benchmark model. 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. This assumption is necessary for an equilibrium with zero long run growth of consumption to exist. 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.

We are left with calibrating ψ, the capital adjustment cost parameter. We match the observed standard deviation of the investment to output ratio before 1995. The resulting aggregate adjustment costs amount to a negligible fraction of GDP.

Having set all parameters, we calculate the path our model predicts for inputs and output under two assumptions on agents' expectations. In the first experiment (perfect foresight, PF) we assume that agents know the entire sequence of exogenous shocks shown in Figure 2 before making any decision. In the second experiment (perfect surprise, PS) we assume that agents foresee all shocks up to the last quarter of 1994. After 1994, agents expect all shocks other than the interest rate to permanently assume their average values before 1995. As for the interest rate, households expect it to be constant at $\frac{\beta^{-1}-1}{1-\tau^k_{average}}$, the only value compatible with zero long-run consumption growth, where $\tau^k_{average}$ is the average capital income tax rate before the crisis.

In other words, under the PS scenario, 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 of future shocks to the correct path. We view this experiment as an approximation to a situation where households assign a positive but very small probability to the possibility of a crisis in 1995.

These simplifying assumptions on expectations enable us to use a simple non-linear solution method. Specifically, first order conditions from the firm and the household problems' imply that the evolution of capital in this model

[21] The elasticity of labor supply is $\frac{1}{\nu-1}$.

is described by the following second-order difference equation for all t:

$$1 + r_{t+1}(1 - \tau_{t+1}^k) = \frac{1 + \left(\alpha_k \frac{y_{t+1}}{k_{t+1}} - \delta\right)\left(1 - \tau_{t+1}^k\right) + \psi\left(k_{t+2} - k_{t+1}\right)}{1 + \psi\left(k_{t+1} - k_t\right)}. \tag{3}$$

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 when exogenous variables stay at their level in the first quarter of 2003 forever. The equilibrium path for other endogenous variables can then be calculated as a function of capital and exogenous shocks.[22] Given the magnitude of shocks in 1995, using linear approximations around the steady state may yield inaccurate results.[23]

3.3 Results

Figure 3 plots the predictions of the model for GDP, labor, and the capital-GDP ratio for both the PF and PS experiments, and compare them to data. Each time series is scaled by its respective value in the last quarter of 1994 to focus on the impact of the crisis.

The key result is that GDP falls approximately twice as much in percentage terms as in the data, under both expectation scenarios. This is true, in other words, whether or not agents saw the crisis coming. In the PF experiment, GDP falls by 18.5% between the last quarter of 1994 and the last quarter of 1995 while GDP falls by 18.1% in the PS experiment. Recall that, in the data, GDP falls by 9.7% in 1995. In fact, because TFP remains low until the end our sample, the model also vastly underpredicts the strength of the recovery.

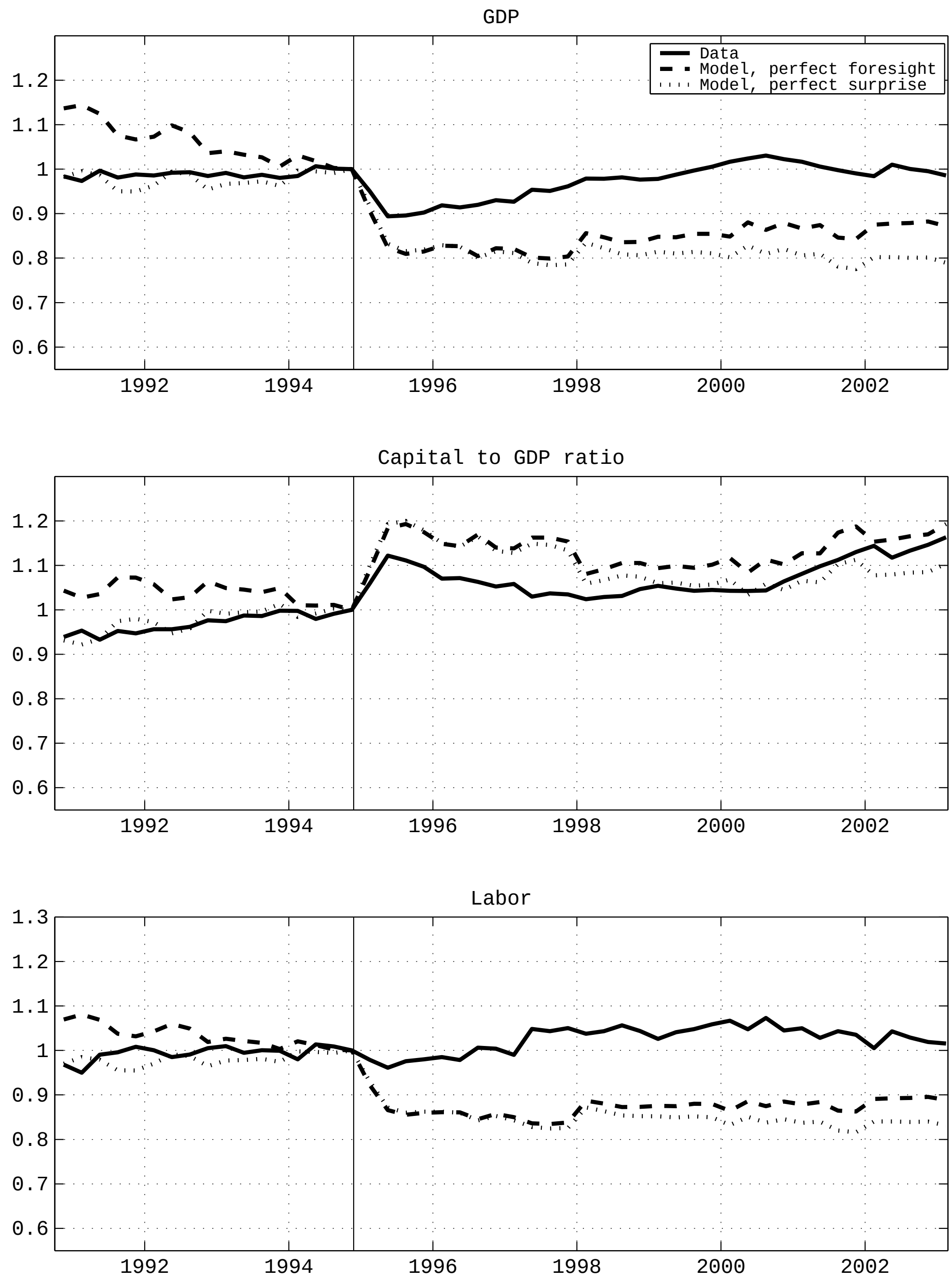
The excessive fall in output stems from the fact that labor falls more than two times as much as in the data, under both expectations scenarios. Given the collapse of TFP in 1995, the model predicts that wages and labor should fall much more than they do in the data. In addition, since TFP never recovers fully, predicted labor remains counterfactually low until the end of our sample period.

The two experiments make very different predictions for the behavior of output and inputs before the crisis. In the PF experiment, the capital-output ratio falls before 1995 as agents anticipate the crisis. This makes all variables fall in anticipation of the large changes in exogenous variables in 1995. Series

[22]See the computational appendix.

[23]Otsu (2006) compares various numerical methods and assumptions on expectations in the case of Korea's 1997-98 crisis and finds that results all resemble those one obtains with our method.

Figure 3: Predictions of the benchmark model



predicted by the PS experiment track their empirical counterparts more closely as agents base their investment decisions on optimistic expectations.

For similar reasons, the two experiments also have different implications for the behavior of consumption and the trade balance.[24] In the PS experiment, agents experience a very large wealth shock in 1995 combined with unexpectedly high interest rates. Correspondingly, consumption falls more than output and the trade balance goes from negative to positive when the crisis hits, much like it does in the data. Because of the counterfactually large response of output, the trade balance correction is too large as well, but it returns to levels close to the relevant data by the end of our sample period. In the PF experiment, agents know that leaner years are ahead and accumulate assets (the trade balance is positive) before the crisis. Following the crisis, the rate of asset accumulation slowly declines and eventually becomes negative. Therefore, the model correctly predicts a sudden stop in 1995 as long as agents have optimistic expectations before the crisis.

To measure the relative role of the many shocks that hit the Mexican economy in 1995, we carry out PS experiments where, after 1994, only one of the exogenous shocks takes its observed values. We find that the effect on output of the TFP shock is much larger than the effect of any of the other shocks. The fall in output in the TFP experiment is 15%.

The magnitude of the TFP shock is the cause of the model's counterfactually large fall in output, and the lack of a recovery. The benchmark model's difficulties in matching the behavior of output and inputs during and after Mexico's 1995 crisis do not stem from fiscal shocks.

3.4 Sensitivity analysis

This section discusses the robustness of the previous findings to our assumptions on the utility function.

Elasticity of labor supply

Our findings are sensitive to the assumed elasticity of labor supply. In particular, a higher ν would render labor supply less elastic, which reduces the predicted fall in hours worked, hence in output in 1995. In fact, it is clear that one can find a value for ν such that the model will predict the correct fall in hours worked during the crisis.

[24] In computing the consumption path, we 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. This is approximately the value reported in Lane and Milesi-Ferretti (2001).

Setting $\nu = 4.33$, which is at the upper bound of the range of estimates discussed by Greenwood et al. (1988), produces a fall in hours in 1995 that resembles the fall in the data, as displayed on the left-hand side of figure 4.[25] The same is true for the behavior of GDP, and the model predicts a recovery in GDP very similar to the one observed.

However, such a value for ν predicts a counterfactually stable path for labor input outside the crisis. The standard deviation of predicted hours before the crisis and over the full length of our sample is much lower than in the data (the ratio is 52.9% for the full period). In short, it is not possible to find a value for ν such that the model yields a reasonable path for hours worked both during and outside of the crisis period.

Standard utility function

Heretofore we have assumed a utility function such that the wage elasticity of labor supply is exogenous and invariant over time. As we have mentioned, this function is typically used in small open economy models because it improves the model's consistency with business cycle regularities. It is interesting nonetheless to consider the impact of giving households a function that is more standard in closed economy exercises.

Specifically, assume that households now order consumption and labor supply sequences $\{c_t, l_t\}_{t=0}^{+\infty}$ according to the following intertemporal utility function:

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

where $\rho > 0$ measures the weight of leisure in utility. Households face the same budget constraint as before.

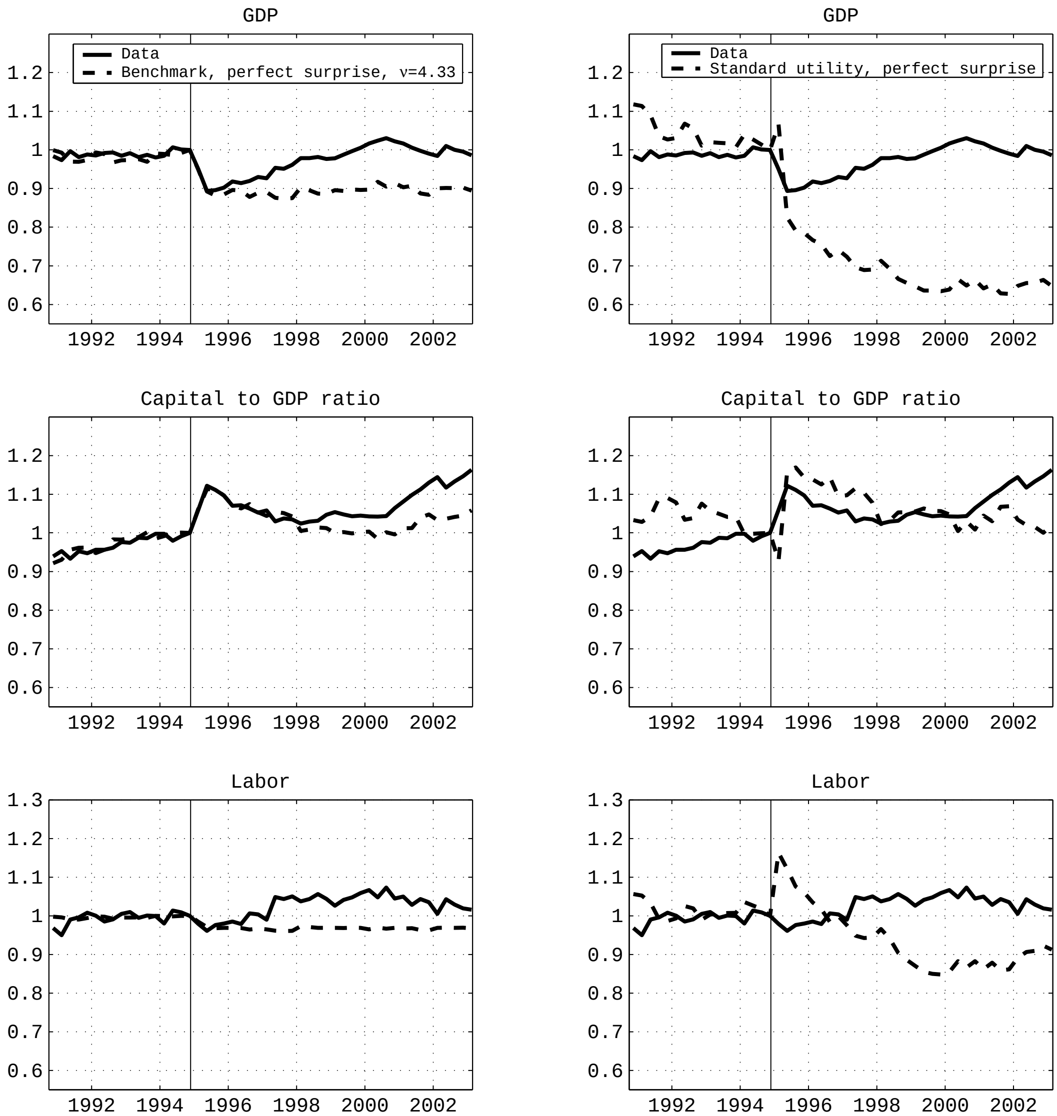
Solutions to the household problem must satisfy, for all t:

$$\frac{c_{t+1}}{c_t} = \frac{\beta(1+\tau_t^c)}{1+\tau_{t+1}^c}(1 + r_{t+1}(1 - \tau_{t+1}^k)) \quad (4)$$

$$\frac{\rho c_t}{1 - l_t} = \frac{w_t(1 - \tau_t^l)}{1 + \tau_t^c}. \quad (5)$$

[25] The figure shows the perfect surprise case only to reduce clutter. Results are similar in the perfect foresight case. As is well-known (see Blundell and MaCurdy, 1999, for a review), much of the existing microeconomic evidence suggests that the elasticity of labor supply is in fact quite low, particularly for male workers. The fact that these low estimates result in counterfactually low variation of hours at a business cycle frequency in macroeconomic models such as ours is also well documented.

Figure 4: Low elasticity of labor supply, and standard utility



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), (5) can be rearranged to read, at date t:

$$l_t = \left(1 + \frac{(1+\tau_t^c)\rho c_t}{(1-\tau_t^l)\alpha_n y_t}\right)^{-1} \tag{6}$$

Condition (6) shows how a standard utility function could help account for the behavior of hours worked in 1995. Hours worked are now a function of the consumption-output ratio. If the model predicts a fall in consumption comparable in relative 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 paths of consumption, hours worked, assets and capital that satisfy (4), (6), the household's budget constraint, and the same difference equation in capital as before. In implementing the algorithm described in the computational appendix, we set ρ to match the average level of hours worked before the crisis.[26] To match the fact that hours have no trend before 1995, we set the rate of time preference to the average net interest before the crisis, and set long term interest rates accordingly in our two expectation scenarios.

The model performs very poorly under perfect foresight, for obvious reasons. In this model, consumption rises at the after-tax rate of interest net of the rate of time preference. Since interest rates are very high in 1995, consumption rises throughout the year (see equation 5) while TFP falls markedly. Correspondingly, the consumption-output ratio rises markedly and hours worked fall even more drastically than in the previous model.

Under a perfect surprise scenario, agents adjust consumption hence hours in the first quarter of 1995 after discovering the true path of exogenous series.[27] In particular, consumption must be adjusted downward since agents

[26] As before, we 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.

[27] The right-hand side of figure 4 shows results for a perfect surprise experiment where agents expect TFP to assume its average over the sample including 1995, instead of its pre-crisis average. Using the pre-crisis average for TFP leads to an even sharper contraction of output once the crisis hits.

realize that their future income will be much lower than expected. In fact, the consumption-output ratio actually falls, so that hours *rise* in the first quarter, as the right-hand side of figure 4 shows.[28] However, this effect is short-lived, as consumption then starts rising steeply due to high interest rates. Hours adjust downward and eventually bring output, hours and capital markedly below trend. In other words, once agents have adjusted to the crisis, output and input series fall well below their data counterpart, much more in fact than under our benchmark specification of preferences.

The basic problem is that given persistently high interest rates after the crisis, the model predicts that consumption should rise faster than output, and that, correspondingly, hours should fall for several periods, which is at odds with the evidence. If one sets the rate of time preference to offset the high interest rates that prevail after the crisis, predicted hours trend steeply up before the crisis when interest rates are relatively low, which is also at odds with the evidence.

This is a manifestation of the difficulties the standard utility function presents for open economy models. Because interest rates are volatile and display large, persistent deviations from their average values in economies such as Mexico, predicted hours worked display counterfactually large fluctuations.

4 Factor utilization

The fact that the predictions for inputs deviate drastically from their empirical counterparts suggest that factor utilization could play a big role during crises. Intuitively, financial crises create ideal conditions for big swings in capital utilization and labor hoarding. Productivity is much below trend while interest rates are much above average for a relatively short period of time which gives firms strong incentives to postpone the use of capital and labor services.

Standard statistics also point to a significant decline in factor utilization during the crisis. Our computational appendix describes how one can construct a comprehensive measure of energy use by the business sector in Mexico along the lines suggested by Atkeson and Kehoe (2001). That index declines by 8% according to our calculations in the first quarter of 1995 and slowly recovers to its pre-crisis level by the middle of 1996. Similarly, data on workplace accidents available from Mexico's social security administration show a significant drop in 1995: 21.2%. These numbers are all consistent with a marked decline in utilization during the crisis, which could explain a large part of the TFP drop.

[28] See Otsu (2006) for similar results in the case of Korea's crisis.

In this section, we use standard models of factor utilization to quantify the importance of capital utilization and labor hoarding.

4.1 Capital utilization

Consider a small open economy model with variable capital utilization modeled as in Greenwood, Hercowitz and Huffman (1988). The household's problem is the same as in the benchmark model, but firms can now 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.[29]

Specifically, depreciation at date t depends on utilization u_t as follows:

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

where $\phi > 1$. Output at date t is now given by:

$$z_t^u \left(u_t k_t^f\right)^{\alpha_k} n_t^{\alpha_n}.$$

Firms continue to take all prices as given and choose $k_t^f, n_{t,}$ and u_t each period to maximize:

$$z_t^u \left(u_t k_t^f\right)^{\alpha_k} n_t^{\alpha_n} + \quad 1 - \frac{u_t^{\phi}}{\phi}\Bigg) k_t^f - k_t^f \left(1 + r_t^k\right) - n_t w_t.$$

This maximization problem yields the following condition for optimal utilization at date t:

$$u_t = \left(\alpha_k \frac{y_t}{k_t}\right)^{\frac{1}{\phi}}, \tag{7}$$

as in Greenwood, Hercowitz and Huffman (1988).

It follows that the capital-output ratio path implies a unique utilization path. Given measures of the capital to output ratio and a value for ϕ, TFP net of changes in capital utilization can then be computed at date t as:

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

While no further adjustment to national accounts data is needed to imple-

[29] Gertler, Gilchrist and Natalucci (2003) also combine the framework in Greenwood et al. (1988) with a small open economy model.

ment 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 ϕ we calculate utilization as defined by condition (7). Then next period's capital stock can be calculated using the following law of motion:

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

where i_t is gross capital formation. Proceeding recursively yields a path of capital, utilization and therefore of TFP adjusted for changes in capital utilization.

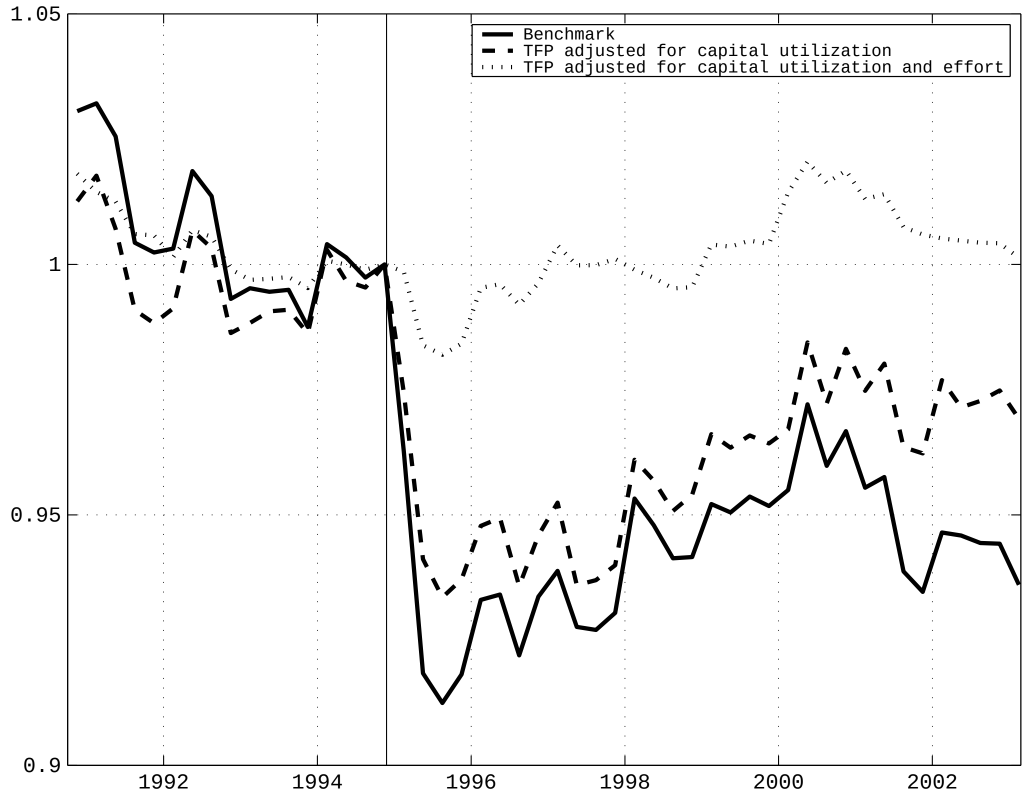
Implementing this procedure requires a value for ϕ, the curvature of the depreciation schedule. Simple algebra shows that in this model the steady state depreciation rate is equal to $\frac{r}{\phi-1}$ where r is the steady state rate of interest. We choose $\phi = 1.44$ to imply a steady state yearly 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.[30] We also experimented with different values of ϕ, including a value such that the implied steady state depreciation rate is 5% on a yearly basis. The quantitative results are practically the same in all cases.

Because our measure of the capital-output ratio falls in 1995, utilization does as well. This makes intuitive sense. Adjusted TFP falls by a large amount in the first quarter of 1995 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 measured utilization fell 5.4% between the last quarter of 1994 and the last quarter of 1995. This implies that TFP adjusted for capital utilization falls less than conventionally-measured TFP (6.3% versus 8.2%), as shown in figure 5. 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 conventionally-measured TFP.

The key question is whether making capital utilization endogenous improves the ability of the model to account for the behavior of output and inputs. To answer that question, we first recalibrate parameters to continue matching our calibration targets. Figure 6 plots the predictions of the model

[30] This value for ϕ is close to values used in studies of the U.S. economy. Greenwood et al. (1988) use $\phi = 1.42$ to imply a steady state yearly depreciation rate of 10%. Burnside and Eichenbaum (1996) estimate ϕ to be 1.56 in the U.S.

Figure 5: TFP adjusted for endogenous capital utilization and labor hoarding



for GDP, labor, capital and utilization, under the PS scenario.[31]

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 1995. In particular, GDP falls by 21.7%, even though TFP adjusted for capital utilization falls less than conventionally-measured TFP.

The reason for this is simple. When confronted with exogenous shocks, firms can adjust labor as before, but they can also vary capital utilization. This new margin of adjustment magnifies the economy's response to productivity shocks.[32] The predicted fall in utilization in 1995 (13.2% in the PS experiment) is higher than in the data as the model predicts a greater increase in the capital-output ratio than in the data. Finally, like in the benchmark model, TFP, adjusted in this case for changes in capital utilization, accounts for most of the fall in output.

In summary, including variable capital utilization helps account for some of the variance of conventionally-measured TFP but does not improve the performance of the model during 1995. The model continues to predict that output and inputs should fall twice as much as observed in 1995.[33]

4.2 Labor hoarding

Assume now that firms and households can use yet another margin of adjustment when confronted with exogenous shocks: effort. We model labor hoarding in the spirit of Burnside et al. (1993).[34] Time devoted to work by households is indivisible: employed households devote time $f > 0$ to work while unemployed households devote no time to work. As in Hansen (1985)

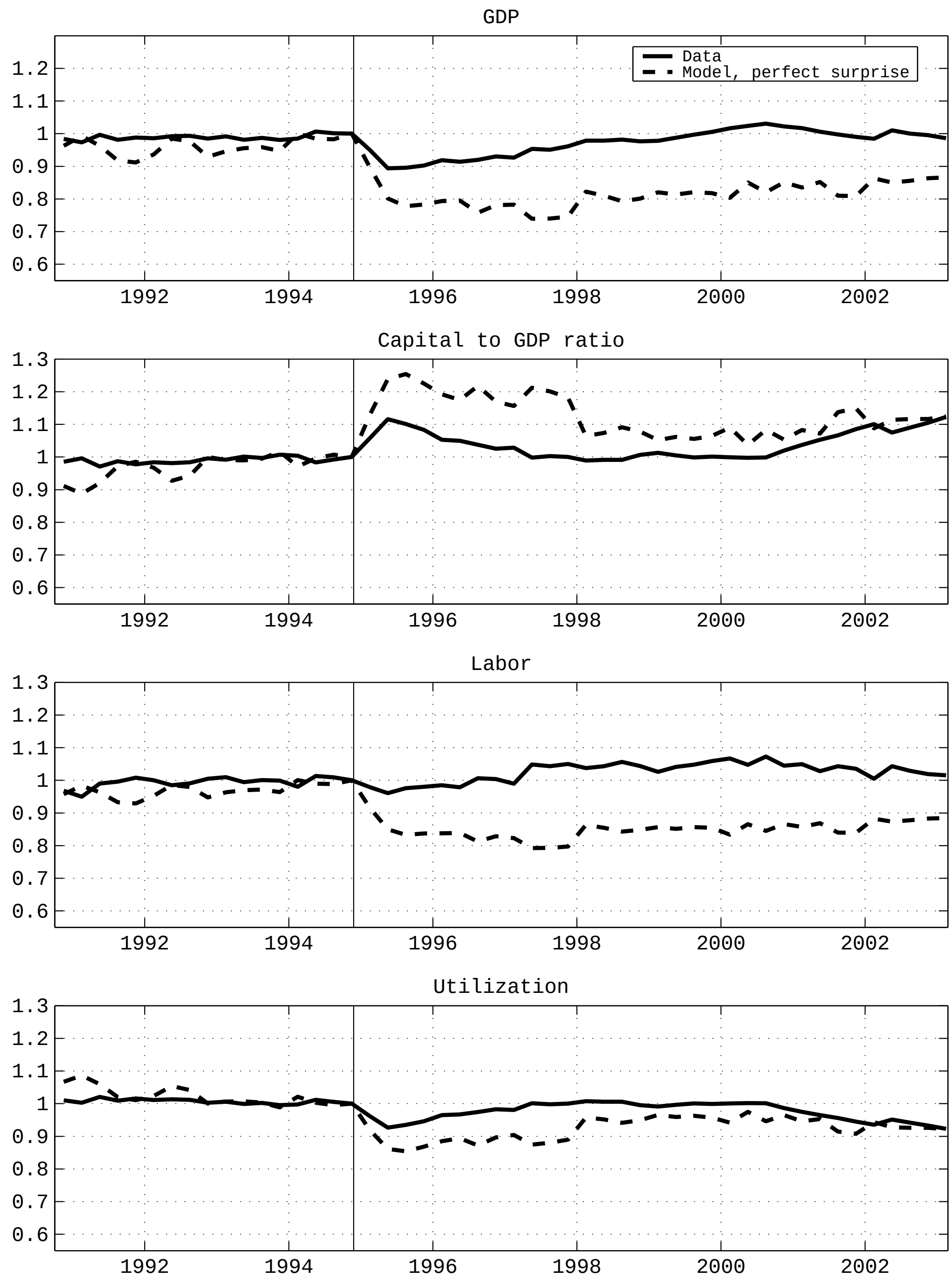
[31] We do not show the results of the PF experiment to reduce clutter. Results are very similar to those we obtained with the benchmark model with one exception: the capital-output ratio is much more volatile under perfect foresight than in the perfect surprise experiment.

[32] This is consistent with the findings of Burnside and Eichenbaum (1996). They find 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.

[33] One can complement this exercise using US evidence on the elasticity of capital utilization to GDP during recessions. We used data on the workweek of capital, which Beaulieu and Mattey (1998) discuss in detail, to approximate the percentage fall in capital utilization as a linear function of the percentage fall in GDP during US recessions. Applying this ratio to Mexican data yields a smaller fall in TFP during the Tequila crisis hence a smaller fall in predicted GDP. Nevertheless, the fall in GDP continues to far exceed its data counterpart. Details of these calculations are available upon request.

[34] Baxter and Farr (2001) construct a two-country model with utilization modeled as in this paper and with labor hoarding as in Bils and Cho (1994). Baxter and Farr (2001) find that variable labor utilization modeled in such a way does not enhance the response of output to productivity shocks.

Figure 6: Predictions of model with endogenous capital utilization



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 effort when employed. We further assume that working entails a fixed cost $\kappa > 0$.[35] Households maximize:

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

subject to, for all t:

$$\begin{aligned} & \left(l_t c_t^e + (1 - l_t) \, c_t^u \right) (1 + \tau_t^c) + k_{t+1} + a_{t+1} \\ = \; & l_t f \epsilon_t w_t \left(1 - \tau_t^l\right) + a_t(1 + r_t \left(1 - \tau_t^k\right)) + k_t(1 + r_t^k \left(1 - \tau_t^k\right)) \\ & - \frac{}{2} \left(k_{t+1} - k_t \right)^2 - C(l_t, l_{t+1}) + T_t. \end{aligned}$$

where C denotes employment adjustment costs. Below, we will discuss results for various specifications of this function.[36]

The form we assume for the household utility function implies that 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 short-run wage elasticity of aggregate labor supply is governed by exogenous parameter $\nu > 1$, and is independent of income and consumption.

Output in this environment is given for all $t \geq 0$ by:

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

where ϵ_t^f is the representative firm's effort choice, n_t is the fraction of households that they employ, and $z_t^{u,h}$ is TFP adjusted for both capital utilization and labor hoarding.

In equilibrium, $n_t = l_t$ and $\epsilon_t = \epsilon_t^f$ for all t. One easily shows that optimal behavior on the part of firms and households in this environment imply the

[35]If there is no such cost, it is efficient for households to work with probability one in every period.

[36]Without such costs, one easily shows that the optimal effort level is constant across periods.

following condition for effort in equilibrium:

$$\epsilon_t = \left(\frac{\alpha_n (1 - \tau_t^l) y_t}{(1 + \tau_t^c) n_t f^\nu} \right)^{\frac{1}{\nu}}. \qquad (8)$$

Effort, therefore, depends negatively on both the tax on labor and the tax on consumption.[37]

Calibrating ν is difficult since independent evidence on this parameter is not available. We chose to experiment with various values centered around $\nu = 1.5$, the value we used for the curvature of the disutility of labor in the benchmark model. The fixed length of work f is set to 0.45. This number corresponds to average hours per worker before 1995, relative to approximate discretionary time available in a quarter, 1300 hours.

These parameters are sufficient to infer effort from the observed path of hours worked $n_t f$ and output. Figure 5 shows the behavior of TFP adjusted both for changes in capital utilization and for changes in effort when $\nu = 1.5$.[38] Combined, capital utilization and effort account for approximately 80% of the fall in conventionally-measured TFP in 1995. Note that factor utilization accounts for much of the variance of conventionally-measured TFP outside of the crisis as well.

We want to ask whether making effort variable improves the consistency of the model with evidence. To that end, we now need to be explicit about adjustment costs.

Assume first that households who change their work probability from l_t to l_{t+1} in period $t+1$ bear quadratic costs $\frac{\psi_l}{2}(l_{t+1} - l_t)^2$ where $\psi_l > 0$, as in Cogley and Nason (1995).[39] In that case, one shows that the behavior of capital and labor is described by two simultaneous second-order difference equations. In experimenting with this specification, we chose κ to match the initial level of employment in our sample. Following our previous calibration strategy, the natural way to choose a value for employment adjustment cost parameter ψ_l is to match the standard deviation of employment before the crisis. However, we found that doing this led to unreasonably large fluctuations in employment

[37] Details are available in the computational appendix.

[38] Results for a variety of other values of ν are available upon request. Reducing ν increases the elasticity of effort, and effort accounts for a greater share of the variance of TFP when ν is low. At the same time, for all values of ν considered, effort accounts for a large fraction of the volatility of TFP, both during and outside of the crisis.

[39] As in the case of 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.

after the crisis.

To keep employment within reasonable bounds, we choose a value of ψ_l such that n_t remains between 40% and 60% throughout the simulation period in all experiments. Given this compromise, predicted hours worked are very smooth in all cases and, not surprisingly, predicted GDP falls little in 1995 under both expectations scenarios.[40] However, the relatively good behavior of the model during 1995 is short-lived. As labor slowly adjusts, GDP remains below its data counterpart by magnitudes quite similar to what we obtained in the benchmark economy.

Given the calibration difficulties the previous specification presents, assume instead that adjustment costs in period t are $\frac{\psi_l}{2}(l_t - \bar{l})^2$ where $\bar{l}$ is the steady state level of employment. In this case, it is deviations from employment's long-run level that are costly. As in the quantitative exercises of the previous section, we can now choose ψ_l and ψ_k to match the pre-crisis volatility of employment and the investment to GDP ratio. We choose κ so that $\bar{l}$ matches the average level of employment in our 1990-2003 sample. At the onset of the crisis, employment is near this average level both in the data and in our simulations.

Figure 7 shows the predictions of this version of the model under the PS scenario. It improves upon the models we have considered so far in several key respects. Hours worked fall much less than in all previous cases during 1995 as does output. Although both continue to drop more than in the data, the discrepancy between the model's predictions and the evidence becomes much smaller. Predicted GDP falls 14.4%, compared to 18% or more in previous models.

Note also that the model closely approximates the true path of the capital output ratio hence makes markedly improved predictions for the path of capital utilization relative to the model with fixed effort. Predictions for effort are remarkably close to their data counterpart as well. Here, the data measure for effort is obtained using expression (8) given data for output, total hours worked, and tax rates.

Finally, while the model continues to underpredict the strength of the recovery, the gap between predictions and the evidence is not nearly as marked as in previous models. By the end of our sample period, output is 6% below its data counterpart in this model, compared to 11.5% in the model with variable capital utilization but fixed effort, and compared to over 20% in the benchmark model.

We performed extensive sensitivity analysis to verify that the broad nature

[40]These results are available upon request.

Figure 7: Predictions of model with labor hoarding

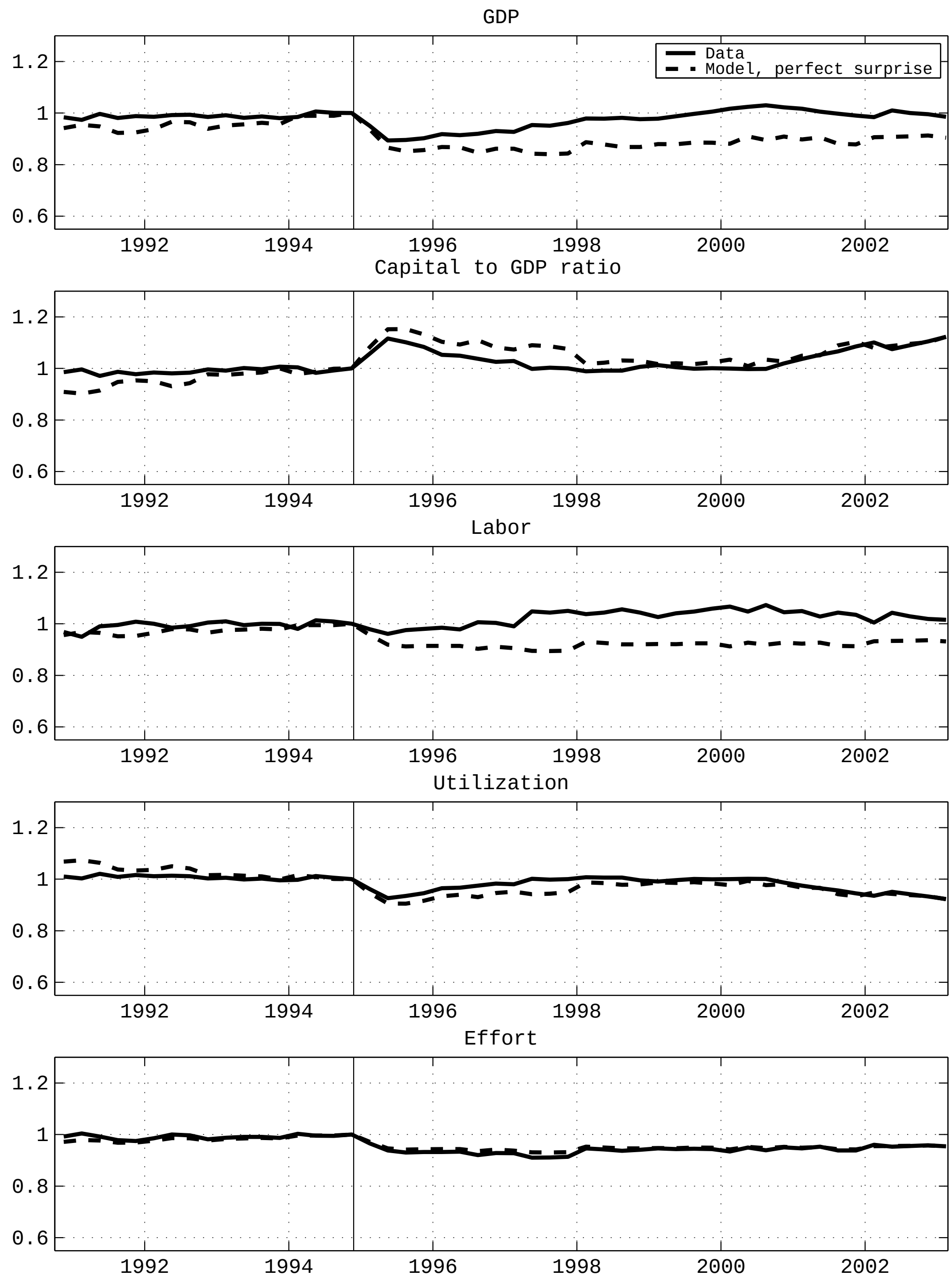


Table 1: Counterfactual experiments

	All shocks	Interest rate shock	Consumption tax shock	Labor tax shock	TFP shock	No shock
GDP	-14.4	-1.5	-3.8	2.5	-7.3	1.7
Capital	-3.1	-2.0	4.6	4.9	5.3	5.4
Labor	-8.6	-1.1	-3.2	1.0	-4.1	0.4
Measured TFP	-8.0	-0.1	-5.5	0.3	-6.0	-0.2

Notes: The impact of each shock is measured as the percentage change in endogenous variables in 1995 when all but one of the exogenous variables assume their pre-crisis average after 1994.

of these results does not depend on the details of our calibration strategy. For instance, we found that letting ν vary from 1.1 to 3 has little effects on our basic results. So does specifying expectations so as to match the pre-crisis behavior of the capital-output ratio.[41]

Overall, introducing labor hoarding improves the model's performance during the crisis and during the recovery period, compared to the benchmark model or the model with variable capital utilization but fixed effort.

In addition, this version of the model yields a very different message as to what accounts for the real impact of the Tequila crisis. Whereas in all previous models TFP alone accounts for most of the behavior of output, this is no longer true once one introduces labor hoarding.

Table 1 shows the results of counterfactual experiments in which all but one exogenous variable assumes its value under our optimistic, perfect surprise scenario. In other words, in these calculations, we subject the economy to only one shock at a time in order to isolate the contribution of each variable to the model's behavior in 1995. As the table shows, the interest rate shock would have caused output to fall by 1.5% in 1995, instead of rising by 1.7% in the

[41] We also experimented with a specification of adjustment costs where, as in Burnside and Eichenbaum (1993), adjusting employment takes time. Clearly, such a constraint only binds in the case where agents are surprised by the crisis. Consider a model where, in addition to facing the same costs as above, employment plans must be announced four quarters in advance. Not surprisingly, the model performs very well for exactly four quarters after the onset of the crisis, but as soon as employers can adjust their labor plans, predicted GDP and hours worked jump very close to their value predicted by the model without time-to-adjust constraints.

absence of any shock.[42] The consumption tax shock causes output to fall by 3.8%. The behavior of the labor tax, for its part, has no negative impact on output in 1995. Adjusted TFP ($z^{u,h}$) has the largest impact of all shocks, as standard TFP does in the benchmark model. However, notice that, by itself, it accounts for about half of GDP's behavior in 1995, while the rest stems from the presence of fiscal and interest rate shocks.[43]

Note also that the model predicts that TFP measured assuming that factor utilization is constant falls by 8% even though adjusted TFP only falls by 1.6%. The response of factor utilization greatly magnifies the response of output to the exogenous shocks.[44]

5 Conclusion

In this paper, we document that conventionally-measured TFP falls by unusual magnitudes after most financial crises, and find that in the case of Mexico's Tequila crisis, factor utilization can account for much of this productivity fall. Most importantly, augmenting the standard small, open economy model to allow for endogenous factor utilization significantly reduces the gap between predictions for output and hours worked and data.

Given the behavior of hours worked and employment, it is perhaps not surprising that labor hoarding accounts for much of the unusual drop in conventionally-measured TFP during the Tequila crisis in Mexico. In fact, we expect similar results to arise in the case of Indonesia and Thailand's recent collapses.

In episodes such as South Korea's 1997 crisis however, hours behave much more closely to what a standard neoclassical model would predict. Differences in labor market regulations in Mexico and Korea are a natural potential explanation for the different impact of crises on labor measures in the two countries. As Koo and Kiser (2001) discuss, a significant change in layoff regulations in February 1998 facilitated employment adjustment in Korea. There was no comparable change in regulation in Mexico during the Tequila crisis.

[42] In this experiment, we also set the capital tax rate to its PS value so that an equilibrium with constant long-run consumption continues to exist.

[43] Meza (2007) finds a significant quantitative role of changes in the consumption tax on GDP in Mexico in 1995 using a closed economy model.

[44] Counterfactual experiments also reveal that it is the persistence of fiscal shocks that explain the fact that the model continues to underpredict the strength of the recovery. Absent fiscal shocks, predicted output recovers as strongly as it does in the data which is not surprising since adjusted TFP quickly returns to pre-crisis levels.

In cases such as the one of Korea, labor hoarding is likely to account for a smaller part of the behavior of TFP than in Mexico, and other explanations for the sharp fall in measured productivity should be explored.

For instance, sharp devaluations are often followed by marked changes in the distribution of employment across industries. The fall in productivity could for instance reflect transitory losses in the quality of labor as employees devote time (a fraction of what we treat as hours worked) to learning new skills, among other possible transition costs. We consider this a promising avenue for future research.

The models we describe in this paper also ignore the possible role of financial constraints. One needs a model with a channel from the availability of finance to the efficiency with which factors are allocated (e.g. across sectors of activity or establishments within a given sector) and used, a marked departure from the standard neoclassical framework.

Bergoeing et al. (2002) study the allocation effects of bankruptcy and banking regulations, and argue that regulations that favor certain sectors may have caused the Mexican economy to operate inside the aggregate production possibility frontier over the past 25 years, partly explaining the economy's lackluster performance during that period vis-a-vis nations such as Chile.[45] Productivity may fall during crises because these regulations cause productive firms to be disproportionately affected.

Shocks to the capital accumulation technology could play a role in the behavior of output during crises.[46] However, the ratio of the investment deflator to the consumption deflator increased in Mexico 1995 which is consistent with a *negative* shock to the accumulation technology. This, if anything, would lead one to expect an even greater fall in GDP during 1995 than what our benchmark model predicts.[47]

Studying these hypothesis further should enhance our understanding of the real impact of financial crises, and, in turn, should help us build better models of real economic activity in nations plagued by frequent collapses. Kydland and Zarazaga (2002) use a closed economy version of the neoclassical model to account for Argentina's recent economic history. The most challenging time

[45] Interestingly, they also argue that factor utilization is likely to play an important role in productivity movements during crises, an idea we make formal in this paper. They view distortive regulations as a long-term, persistent drag on aggregate productivity.

[46] Justiniano and Primiceri (2006) have recently found that investment specific technology shocks in the U.S. have become less volatile, which has led to a decline in the volatility of output and other aggregates.

[47] See Greenwood, Hercowitz and Krusell (2000) for a measurement of the effect of investment technology shocks on output.

period for the model begins in the late 1980s, after a lost decade of financial turmoil, and extends past Argentina's Tequila crisis. The model predicts that investment should have fallen much more than it did in the late 1980s, and recovered much faster than it did thereafter. Similarly, the results in Bergoeing et al. (2002) show that a closed economy model's predictions diverge from the evidence around Mexico's Tequila crisis. Output and especially labor fall more than observed in 1995.

Recent depression periods in Latin America are best described as series of financial crises. The closed economy neoclassical growth model's difficulties in accounting for the behavior of output, capital intensity and hours worked in those countries could stem from the fact that it does not account well for the real impact of financial crises.

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