February 17, 2010

The Costs of Emerging Market Financial Crises: Output, Productivity and Welfare

Guido Sandleris*

Universidad Torcuato di Tella

Mark L. J. Wright*

University of California, Los Angeles

PRELIMINARY AND INCOMPLETE

ABSTRACT

Financial crises in emerging market countries appear to be very costly: output falls are often dramatic, while a host of partial welfare indicators – from suicide rates to infant mortality – deteriorate as well. The magnitude of these costs is puzzling both from an accounting perspective – factor usage does not decline as much as output, resulting in large falls in measured productivity – and from a theoretical perspective – we have no theory as to why technology should deteriorate during a crisis, and these economies are usually too closed to international trade for terms of trade changes to have a large effect on welfare. Towards a resolution of this puzzle, we present a framework for measuring the welfare costs of a financial crisis, and for decomposing these welfare costs into the contributions from changes in technology, in the efficiency of the resource allocation mechanism, in the efficiency of government spending, and in the terms of trade. We apply this framework to the Argentine crisis of 2001 using a combination of national accounts and establishment level data.

*We thank ... for comments, and Fernando Giuliano for outstanding research assistance. Further comments welcome. Sandleris: gsandleris@utdt.edu. Wright: mlwright@econ.ucla.edu.

1 Introduction

Financial crises in emerging market economies appear to be very costly: declines in economic activity are often very large, while a host of social indicators suggest that welfare falls substantially too. For example, in Argentina in the months surrounding the sovereign default and devaluation around the end of 2001, output fell by 15 per-cent in one year, and by more than 20% from its previous peak. Unemployment climbed to over 20% and poverty rates almost double leaving approximately half of the population below the poverty line. In the countries affected by the Asian crisis of 1997, increases were reported in poverty rates (in Indonesia they more than doubled), child mortality rates (in Indonesia by 30%), domestic violence (in Malaysia by 20%), murders (Thailand 27.5%) and suicides (in Korea by 20%)[1].

The magnitude of the output declines is hard to explain. From a simple accounting perspective, usage of factor inputs declines by less than output, resulting in a large decline in measured productivity. From a theoretical perspective, we have no theory as to why technology should regress during a crisis, and while measured productivity might decline due to declines in factor utilization, changes in utilization do not appear large enough to explain observed declines. Aside from a decline in productive capacity, it is also not clear why output should decline: the declines in a nation´s capital stock during a crisis tend to be moderate, and in any case have only a modest output elasticity, while the decline in wealth produced by the crisis could be expected to result in greater labor supply. Finally, although welfare might be expected to fall as a result of a deterioration in a country's terms of trade, few countries are sufficiently open to international trade for this to have a very significant effect.

One possible hypothesis to explain the decline in output and productivity is that resources are allocated more inefficiently during crises. This paper presents a framework for measuring this effect. We write down a theoretical framework that nests many of the features of some commonly used models of open economies, and use it to derive relationships between resource allocation, theoretical TFP, output and the welfare of consumers in the model. We then derive the relationship between these objects in the model, and their analogues in the data, demonstrating that there will often be substantial differences as a result of measurement

[1] See Suryahadi et al [37] (poverty rates), Bhutta et al [8] (child mortality), Shari [34] (domestic violence), Knowles et al [22] (murders), Lee [23] (suicides).

assumptions adopted in many countries. The result is a framework that allows us to relate changes in welfare to changes in measured economic activity and productivity, and to relate them to changes in the underlying economic environment in which production takes place.

We then apply our framework to data from Argentina for the period 1997 to 2002. Using a unique micro dataset on the behavior of Argentine manufacturing establishments throughout this period, we find that measured productivity in the manufacturing sector declines by 13% between 2002 and 1997. Approximately half of this decline is explained by a change in the efficiency with which resources are allocated. The key component of this decline is a less efficient allocation of resources across sectors, but there seems to be also a less efficient allocation of resources across plants within each sector.

In order to relate these effects to changes in welfare we use national accounts data for Argentina. We find that the cummulative decline in Argentine welfare was almost 22% between 1997 and 2002. Our model based decomposition of this decline shows that it was caused predominantly by the decline in measured productivity, although this decline is determined to be significantly overstated as a result of measurement errors in the national accounts.

This paper builds on several literatures. Like Chari, Kehoe and McGrattan [9], Meza and Quintin [24], Benjamin and Meza [7], Kehoe and Ruhl [20], Christiano, Gust and Roldos [11], Neumeyer and Perri [28], Mendoza [25], Mendoza and Yue [27], Arellano and Mendoza [1] and Mendoza and Smith [26], our paper aims to understand the consequences of international financial crises for output and productivity. Unlike all of these papers, our paper presents a framework for interpreting measured changes in economic activity as changes in welfare, and focuses on the role of distortions at a microeconomic level during the crisis in producing aggregate outcomes. Like Domar [12], Weitzman [38], and Basu and Fernald [5] we study the relationship between measured productivity and welfare; unlike these papers, we consider an open economy with a government sector, and with arbitrary unpriced distortions to factor and goods markets. Our emphasis on an open economy is shared by Hamada and Iwata [17] and Kehoe and Ruhl [21]; unlike the latter, we study an economy with unbalanced trade, with a government, and with arbitrary distortions in goods and factor markets, while also analyzing the impact of the different measurement techniques for gross domestic product that

are adopted in practice.

Like Solow [35], Hulten [19], Baily et al [4], Basu and Fernald [5], Petrin and Levinsohn [30], and the work surveyed in Foster et al [13], we study the relationship between technological progress at a firm level, reallocation of factors across firms, and aggregate technology; unlike these papers, we study the role of arbitrary distortions in generating gains from the reallocation of resources. Finally, our study of the role of distortions in the resource allocation mechanism in producing aggregate economic outcomes over time is related to Hall's ([15] and [16]) studies of the effect of imperfect competition on measured productivity, to studies of the role of "wedges" at an aggregate level as in Cole and Ohanian XX and Chari, Kehoe and McGrattan [10], and, finally, to studies of role of distortions in explaining differing development at a point in time as in Restuccia and Rogerson [32] and Hsieh and Klenow [18].

The rest of this paper is organized as follows. Section 2 outlines our framework for analyzing the productivity, output and welfare costs of international financial crises. Section 3 then derives the relationships between these objects as well as between these objects and empirical measures of output and productivity. We also show how several popular theoretical models fit into our framework. Section 4 describes our application of this framework to data on Argentina during the 2001/2002 financial crisis and presents our findings, while Section 5 concludes.

2 The Model

In this section we outline our framework for studying the impact of an international financial crisis on output, productivity and welfare. Consider a world that is deterministic. That is, the agents in the economy can be viewed as having perfect foresight, except with regard to the advent of the international financial crisis, which we model as an unanticipated event. In order to make our approach applicable to data from actual economies, we allow a role for government expenditure to affect welfare. We model the decisions of a single small open economy with unbalanced trade, so that the net foreign asset position of the country is evolving over time. There are many industries producing different goods, with these goods aggregated to form the national accounts expenditure categories. Production takes place in plants that are modeled as acting competitively, although they may face plant specific

distortions that affect their incentive to produce at all, as well as to hire the various factors of production. These distortions allow us to capture a range of different economic environments, including ones with imperfect competition.

2.A Households

Consider a world populated by many identical individuals of unit measure who maximize utility defined over streams of the single consumption good C, leisure $1 - L$, and government spending G, ordered by

$$W_t = \sum_{s=t}^{\infty} \beta^{s-t} \left[U\left(C_s, 1 - L_s\right) + \Gamma\left(G_s\right) \right],$$

where U is the period utility function that depends on private consumption and leisure, and Γ captures the welfare benefits (if any) of government expenditure. The period t begins with the households owning B_t bonds and $\hat{K}_t$ capital. They first decide how much to invest, I_t, which costs P_{It} per unit, and then the entire $K_t = \hat{K}_t + I_t$ is devoted to production this period. The reason for allowing investment this period to affect the amount of capital devoted to production this period, is that we wish to allow the capital stock to respond to the crisis which will occur at the start of a period.

After capital is determined, labor supply decisions are made. Then all factors are paid and consumption occurs with the consumption good costing P_{Ct} per unit. What is left is carried forward into tomorrow as bonds B_{t+1} and depreciated capital

$$\hat{K}_{t+1} = (1 - \delta) K_t = (1 - \delta) \left(\hat{K}_t + I_t \right).$$

The households decisions are made subject to the sequence of flow budget constraints

$$P_{Cs} C_s + P_{Is} I_s + B_{s+1} \leq P_{Ls} L_s + P_{Ks} \left(\hat{K}_s + I_s \right) + \Pi_s - T_s + \left(1 + r_{Bs}\right) B_s,$$

with initial capital and bonds given at time $t = 0$. Here Π_s represents any profits earned by firms which are returned to the household, T_s reflects lump-sum transfers and taxes from the government, and r_{Bs} is the world interest rate, while P_{Ls} and P_{Ks} are the rental rates of

labor and capital respectively. Government spending and transfers are treated as exogenous by the household.

The households problem is a well defined convex problem. If we let $W_t\left(\hat{K}_t, B_t\right)$ denote the value of the households problem at time t given inherited values of capital $\hat{K}_t$ and bonds B_t, then it is straightforward to show that the sequence of value functions satisfy

$$W_t\left(\hat{K}_t, B_t\right) = \max_{C_t, L_t, I_t, B_{t+1}} U\left(C_t, 1-L_t\right) + \Gamma\left(G_t\right) + \beta W_{t+1}\left(\left(1-\delta\right)\left(\hat{K}_t + I_t\right), B_{t+1}\right),$$

subject to

$$P_{Ct}C_t + P_{It}I_t + B_{t+1} \leq P_{Lt}L_t + P_{K_t}\left(\hat{K}_t + I_t\right) + \left(1 + r_{Bt}\right)B_t + \Pi_t - T_t,$$

with K_t and B_t given. As the problem is convex, and under the usual differentiability assumptions on U, we can show that the W_t are differentiable. If we let λ_t denote the households shadow price of resources, the first order necessary conditions for an optimum include

$$\begin{aligned} u_L\left(C_t, 1-L_t\right) &= P_{Lt}\lambda_t, \\ u_C\left(C_t, 1-L_t\right) &= P_{Ct}\lambda_t, \\ \beta\frac{\partial W_{t+1}\left(\hat{K}_{t+1}, B_{t+1}\right)}{\partial B_{t+1}} &= \lambda_t, \\ \beta\frac{\partial W_{t+1}\left(\hat{K}_{t+1}, B_{t+1}\right)}{\partial \hat{K}_{t+1}} &= \lambda_t\frac{P_{It} - P_{Kt}}{1-\delta}, \end{aligned} \tag{1}$$

while the envelope conditions are

$$\begin{aligned} \frac{\partial W_t\left(\hat{K}_t, B_t\right)}{\partial \hat{K}_t} &= \lambda_t P_{Kt} + \left(1-\delta\right)\frac{\partial W_{t+1}\left(\left(1-\delta\right)\left(\hat{K}_t + I_t\right), B_{t+1}\right)}{\partial \hat{K}_{t+1}}, \\ \frac{\partial W_t\left(\hat{K}_t, B_t\right)}{\partial B_t} &= \lambda_t\left(1 + r_{Bt}\right). \end{aligned} \tag{2}$$

2.B Government

Government spending makes up a substantial fraction of GDP for most countries. As a result, our assumptions about how this spending is determined, and about how it is valued, can have a large impact on our estimates of welfare. In what follows, we examine two more-or-less polar cases. In both cases, this spending is financed by a combination of exogenously given distortionary taxes on firms (to be described below) and lump sum taxes. For simplicity we keep the governments budget balanced in each period through an appropriate choice of lump-sum taxes and transfers; this is without loss because, for a given sequence of distortionary taxes, private borrowing will adjust to offset any path of government debt.

In the first case, we treat government spending as *pure waste* so that $\Gamma(G_t) = 0$ for all t, with its level in each period exogenously given. In the second case, we allow the government to choose G_t *benevolently.* In this case, the government's choices satisfy $\Gamma'(G_t) = \lambda_t P_{Gt}$, where λ_t is the shadow price of the household introduced above and P_{Gt} is the price of one unit of the government expenditure good.

2.C Production

We consider an economy with J basic commodities produced in separate competitive industries. Later we will aggregate these basic commodities into the national accounts expenditure aggregates, with the J commodities potentially being used to produce the final consumption good, investment, government spending, exports, or alternatively being used to produce an intermediate good used by all industries.

In each industry j, production takes place in plants of which there are a finite set of *types* indexed by i. A plant's type may evolve over time and denotes the level of its productivity, as well as the size of any distortions imposed on the plant in deciding whether to produce, and how much of each factor to hire. A plant of type i operating in industry j can sell it's output at the market price P_{Y_j} which it takes as given. In order to produce in a given period, the plant must pay a flow fixed cost F_j. We denominate these fixed costs in units of capital that we think of as the physical buildings and structures within which production takes place. The part of capital that is structures is to be distinguished from the part that

is machinery and equipment. Once the fixed cost has been paid, the plant combines capital used for plant and equipment K_i, labor L_i, and intermediate inputs Q_i to produce output according to a Cobb-Douglas production function

$$Y_i = A_i \left[K_i^{\alpha_j} L_i^{\beta_j} Q_i^{1-\alpha_j-\beta_j} \right]^{\gamma_j}.$$

Here A_i is the plant type i specific level of technology; we let A_j denote the average level of technology in industry j and define τ_{Ai} such that $A_i = (1 - \tau_{Ai}) A_j$. The parameter γ_j is assumed to be less than one implying the existence of decreasing returns to scale at the plant level, which we use to pin down the scale of production at a plant.

Plants hire factors on competitive factor markets, taking factor prices as given. In the spirit of Chari, Kehoe and McGrattan's (2002) business cycle accounting, we posit the existence of plant specific *wedges* that distort the hiring decisions of a plant away from what would be chosen if all firms faced the same input prices. Specifically, if we let P_x denote the (common) market price of factor x for $x = K, L$, or Q, and τ_{xi} be the plant and factor specific wedge faced by a plant of type i in hiring factor x, then the effective price faced by a plant of type i is given by $P_x / (1 - \tau_{xi})$. A positive value of τ_{xi} can be thought of as a tax that increases the cost of the factor to the firm. We also let τ_{Fi} capture any distortions to fixed costs which affect the incentive of a plant to produce in a given period. One could, in principle, also consider a wedge that affects the output price received by an individual plant. However, it is straightforward to see than an output wedge is equivalent to a constant wedge affecting all factor inputs and the fixed cost in the same way.

We interpret these wedges as a *stand-in* for all of the costs of hiring factors beyond the market price of the factor itself. Thus wedges may capture the presence of government taxes, adjustment costs to varying factors, or the effect of rationing due to quantity restrictions or borrowing constraints. Below, we will use data on actual hiring decisions to identify the sizes and characteristics of these wedges, and will refer to *changes* in the size and pattern of these wedges as the impact of the financial crisis on the resource allocation mechanism, as wedges distort the way in which production is carried out across different plants. That is, we do not take a stand on the factors generating non-zero wedges in general, but interpret changes in

these wedges as a (direct or indirect) consquence of the financial crisis.

A plant of type i in industry j that decides to produce in a period chooses factor inputs to maximize profits given by

$$\begin{aligned}&P_{Y_j}\left(1-\tau_{Ai}\right)A\left[K_i^{\alpha_j}L_i^{\beta_j}M_i^{1-\alpha_j-\beta_j}\right]^{\gamma_j}\\&-\frac{P_K}{1-\tau_{Ki}}K_i-\frac{P_L}{1-\tau_{Li}}L_i-\frac{P_Q}{1-\tau_{Qi}}Q_i-\frac{P_K}{\left(1-\tau_{Fi}\right)\left(1-\tau_{Ki}\right)}F_j,\end{aligned}$$

so that the first order conditions for an optimum are

$$\begin{aligned}\alpha_j\gamma_jP_{Y_j}Y_i &= \frac{P_K}{1-\tau_{Ki}}K_i,\\ \beta_j\gamma_jP_{Y_j}Y_i &= \frac{P_L}{1-\tau_{Li}}L_i,\\ \left(1-\alpha_j-\beta_j\right)\gamma_jP_{Y_j}Y_i &= \frac{P_Q}{1-\tau_{Qi}}Q_i.\end{aligned}\tag{3}$$

In what follows, we will for simplicity suppress the industry j subscript denoting industries except when comparing different industries.

During a financial crisis, there is often a great deal of turnover in the set of plants that produce. To capture this feature of the data, we will need to allow for entry and exit in our model. We adopt a framework in which the decision to produce in a period is static so that, when taking the model to the data, we do not have to take a stand as to the firms expectations about future production decisions. In particular, we assume that firms must pay the fixed cost P_KF to produce in each period. After paying the fixed cost, firms then learn about their type i which is drawn form a (time varying) distribution given by the probabilities π_i. We assume that the wedge on fixed costs, and that part of the wedge on capital that applies to fixed costs, are levied in lump sum fashion so that they do not affect the firms decision to produce ex post. Entry occurs as long as expected profits are positive, and so in equilibrium we must have

$$\sum_i\hat{\pi}_i\left[\left(1-\gamma\right)P_YY_i-\frac{P_K}{\left(1-\tau_{Fi}\right)\left(1-\tau_{Ki}\right)}F\right]=0.\tag{4}$$

We let N denote the total number of firms that produce in a period. Our assumptions allow

us to work with the data as though there were repeated cross sections of firms.

In this framework, if all firms in an industry faced the same wedges τ_{Ki}, τ_{Li}, and τ_{Qi}, *relative* (although not total) supply of output and usage of factors would be the same across firms in that industry. When we apply our framework to the data, it will be differences in supply and factor usage which will allow us to identify differences in wedges. Noting that as aggregate industry output is given by

$$Y = N \sum_i \pi_i Y_i, \tag{5}$$

relative production is given by

$$\begin{aligned} \frac{P_Y Y_i}{P_Y Y} &= \frac{Y_i}{Y} = \frac{(1-\tau_{Ai})^{1/(1-\gamma)} \left[(1-\tau_{KSi})^{\alpha} (1-\tau_{Li})^{\beta} (1-\tau_{Qi})^{1-\alpha-\beta} \right]^{\gamma/(1-\gamma)}}{N \sum_i \pi_i (1-\tau_{Ai})^{1/(1-\gamma)} \left[(1-\tau_{KSi})^{\alpha} (1-\tau_{Li})^{\beta} (1-\tau_{Qi})^{1-\alpha-\beta} \right]^{\gamma/(1-\gamma)}} \\ &\equiv \frac{(1-\tau_i)}{N \sum_i \pi_i (1-\tau_i)}, \end{aligned} \tag{6}$$

where we have defined $1-\tau_i$ to be the *scale wedge* of the firm given by the above geometric weighted average of the wedges on technology, capital services, labor and intermediate inputs. Proceeding similarly for each factor, we obtain expressions for firm shares of industry factor usage

$$\begin{aligned} \frac{K_i}{K} &= \frac{(1-\tau_i)(1-\tau_{Ki})}{N \sum_i \pi_i (1-\tau_i)(1-\tau_{Ki})}, \\ \frac{L_i}{L} &= \frac{(1-\tau_i)(1-\tau_{Li})}{N \sum_i \pi_i (1-\tau_i)(1-\tau_{Li})}, \\ \frac{Q_i}{Q} &= \frac{(1-\tau_i)(1-\tau_{Qi})}{N \sum_i \pi_i (1-\tau_i)(1-\tau_{Qi})}, \end{aligned} \tag{7}$$

which verifies our intuition that a plant's relative demand for a factor depends in part upon its scale and in part upon the relative wedge it faces for that factor. Note also that these expressions are homogenous of degree zero in the industry wide level of any one or combination of wedges; although the total amount of a factor hired by the industry may change, relative hiring decisions are unaffected by a common change in wedges in an industry.

Finally, it is convenient to note that, by aggregating the firms first order conditions we can obtain expressions for industry factor shares as factions of the production parameters and output weighted average wedges

$$\begin{aligned} \frac{P_L L}{P_Y Y} &= \beta\gamma \sum_i \frac{P_Y Y_i}{P_Y Y} (1 - \tau_{Li}) \equiv \beta\gamma \left(1 - \bar{\tau}_L^Y\right), \\ \frac{P_Q Q}{P_Y Y} &= (1 - \alpha - \beta)\gamma \sum_i \frac{P_Y Y_i}{P_Y Y} (1 - \tau_{Qi}) \equiv (1 - \alpha - \beta)\gamma \left(1 - \bar{\tau}_Q^Y\right). \end{aligned} \tag{8}$$

Defining $\bar{\tau}_K^Y$ analogously, the residual from output after labor and intermediate goods have been paid is

$$\begin{aligned} \frac{P_Y Y - P_L L - P_Q Q}{P_Y Y} &= \frac{P_Y Y - P_L L - P_Q Q}{P_K K} \frac{P_K K}{P_Y Y} \\ &\equiv \mu\alpha\gamma \left(1 - \bar{\tau}_K^Y\right). \end{aligned} \tag{9}$$

Note that if all wedges were zero, and if entrants were perfect substitutes for incumbent firms, then this reduces to total payments to capital.

2.D Industries, Sectors and Aggregation

So far, we have assumed that there are firms producing in J different industries. However, when presenting the household and government, we drew a distinction between three different final goods. Further, when we compare our model to national accounts data, we will be working with five final goods each corresponding to one of the five main national accounts expenditure categories. We move between the J different production sectors and the five different final goods plus the aggregate intermediate input by defining some simple functions that aggregate combinations of the output goods into final expenditure categories. We begin with a relatively general description of these aggregators before showing how a number of popular models map into this framework.

Specifically, we assume that each basic good $j = 1, ..., J$ can be used as an input to producing consumption, investment, government spending, exports, and the intermediate

input good, so that for these j we must have

$$C_{jt} + I_{jt} + G_{jt} + X_{jt} + Q_{jt} \leq Y_{jt}.$$

Output of each good is then combined with the imported good according to an aggregator like

$$C_t = H^C \left(C_{1t}, C_{2t}, ..., C_{Jt}, M_{Ct} \right),$$

for the consumption aggregate, with analogous aggregators for the investment, government spending, export and intermediate input goods. Usage of imports must satisfy

$$M_{Ct} + M_{It} + M_{Gt} + M_{Xt} + M_{Qt} \leq M_t.$$

We assume that each of the aggregators H^k for $k = C, I, G, X, Q$ are homogeneous of degree one, and that they are operated by competitive firms so that each of the P_{kt} homogeneous of degree one functions of the prices of each industry's output and the import price, while the prices of both exports P_{Xt} and imports P_{Mt} are given. In practice, we will identify the prices of each of the national accounts expenditure aggregates with their corresponding implicit price deflators from the national accounts, and so we will not emphasize the properties of these aggregators. However, they are useful in thinking about the process of moving between the model and the data, and it is straightforward to show that a number of popular models fit into this framework:

Example 1. *One-Sector Closed Economy Without Frictions*

In this case, $N = 1$, $H^C(x, M) = H^I(x, M) = x$, *and* $H^G(x, M) = H^X(x, M) = H^Q(x, M) = 0$, *while all of the* $\tau's$ *are equal to zero. It is common to assume that that plants operate with a constant returns to scale production function, in which case* $\gamma = F = 0$ *(although this is not necessary; see, for example, Rossi-Hansberg and Wright 2007).*

Example 2. *One-Sector Closed Economy With Imperfect Competition and No Intermediate Inputs*

This is the framework studied by Hall (1988) and extended by Basu and Fernald (2001), and can be viewed as an extension of the previous case. Although the framework we have

described above is competitive, the equilibrium allocations will be identical for an appropriate choice of $\tau_{Li} = \tau_{Ki} \neq 0$, *reflecting the markup of price over marginal cost (which does not vary over factor inputs). We also impose* $\alpha + \beta = 1$.

Example 3. *One-Sector Open Economy*

Abstracting from adjustment costs in capital, this is the model studied by Baxter and Crucini (1994) which is the same as our first case except $H^C(x, M) = H^I(x, M) = H^X(x, M) = x + M$, *and* $H^G(x, M) = H^Q(x, M) = 0$.

Example 4. *Open Economy With Imported Intermediate Inputs*

This is the case studied by Kehoe and Ruhl (2007) who also assume that labor supply and capital are fixed, so that $U(C, 1 - L) = U(C)$, $\delta = 0$, *and* $H^I(x, M) = 0$, *that trade is always balanced so that* $P_X X = P_M M$ *and* $B_t = B_{t+1} = 0$, *and that* $H^C(x, M) = H^X(x, M) = x$, *while* $H^G(x, M) = 0$ *and* $H^Q(x, M) = M$. *In a leading example, Kehoe and Ruhl specialize to a Leontieff production function between the labor-capital aggregate and imported intermediate inputs.*

Example 5. *Two-Sector Open Economy*

This case captures the model studied by Backus, Kehoe and Kydland (1991) who assume that a country combines a single domestically produced good, that is also exported, with an imported good to produce an aggregate that is used for consumption, investment and government spending. In our framework, this translates to $H^X(x, M) = x$, *and* $H^C(x, M) = H^I(x, M) = H^G(x, M)$.

3 Technology, Productivity, Output and Welfare

3.A Households, Productivity and Welfare

Imagine that the economy described above experiences an international financial crisis at time t. We model the crisis as an unanticipated change in the prices at which goods trade internationally, the world interest rate, and the entire distribution of wedges faced by firms. We think of the crisis as lasting only one period (the extension to a persistent crisis is discussed below when we take the framework to the data). In general, the entire equilibrium allocation will be affected by the shock.

The change in household welfare as a result of the crisis is given by

$$\begin{aligned} dW &= U_C(C, 1-L)\, dC + U_L(C, 1-L)\, dL + \Gamma'(G)\, dG \\ &\quad + \beta \left(W'_K \left((1-\delta)\left(\hat{K} + I\right), B' \right) dK' + W'_B \left((1-\delta)\left(\hat{K} + I\right), B' \right) dB' \right), \end{aligned}$$

where we have dropped the time subscripts and denote future variables with an apostrophe. Substituting for the FOCs of the consumer from (1) and rearranging yields

$$\frac{dW}{\lambda P_V V} = \frac{P_C C}{P_V V}\frac{dC}{C} - \frac{P_L L}{P_V V}\frac{dL}{L} + \frac{\Gamma'(G)\, G}{\lambda P_V V}\frac{dG}{G} + \frac{B'}{P_V V}\frac{dB'}{B'} + \frac{(P_I - P_K)\,\hat{K}'}{(1-\delta)\, P_V V}\frac{d\hat{K}'}{\hat{K}'}.$$

Using the national expenditure identity for real GDP, and denoting the shares of the major national expenditure aggregates by by $\omega_C^E, \omega_I^E, \omega_G^E, \omega_X^E$, and ω_M^E, we obtain

$$\frac{dV}{V} = \omega_C^E \frac{dC}{C} + \omega_I^E \frac{dI}{I} + \omega_G^E \frac{dG}{G} + \omega_X^E \frac{dX}{X} - \omega_M^E \frac{dM}{M}.$$

Similarly, using the current account identity we obtain

$$dB' = P_X X \left(\frac{dP_X}{P_X} + \frac{dX}{X} \right) - P_M M \left(\frac{dP_M}{P_M} + \frac{dM}{M} \right) + (1 + r_B)\, B \left(\frac{dr_B}{1 + r_B} + \frac{dB}{B} \right),$$

where we have allowed dB to be non-zero, despite the fact that it is usually thought of as predetermined, to allow for valuation effects on the stock of net foreign assets and for reductions in debt as a result of a default and debt restructuring. Using the former to substitute for the growth rate of consumption, and the latter to substitute for the change in net foreign assets yields

$$\begin{aligned} \frac{dW}{\lambda P_V V} &= \left(\frac{dV}{V} - \omega_K^V \frac{dI}{K} - \omega_L^V \frac{dL}{L} \right) + \omega_G^E \left(\frac{\Gamma'(G)}{\lambda P_G} - 1 \right) \frac{dG}{G} \\ &\quad + \left(\omega_X^E \frac{dP_X}{P_X} - \omega_M^E \frac{dP_M}{P_M} \right) + \frac{r_B B}{P_V V} \frac{d(r_B B)}{r_B B}, \end{aligned} \tag{10}$$

where we have denoted the factor shares of value added by ω_K^V and ω_L^V.

That is, the change in welfare is given by four terms. The first is a measure of TFP growth, defined as the difference between the growth rate of value added and the factor share

weighted growth rates of capital and labor. The second term captures the welfare effects of any changes in government spending. If government spending is valued by the household and the government determines G benevolently, the marginal value of an extra unit of government spending equals its cost, $\Gamma'(G)\,dG = \lambda P_G$, and this term disappears. If government spending is not valued, then $\Gamma'(G) = \Gamma(G) = 0$ and we should subtract government spending from our measure of gross national income in calculating the the economy's ability to produce income and purchase goods. In what follows we focus on the benevolent government case (although we also present results for the case of purely wasteful government spending).

The third term is an adjustment for changes in the terms of trade; if the price the country receives for its exports rises less than the price it pays for its imports, welfare is reduced. This adjustment differs form the usual terms of trade adjustment used to compute real Gross National Income (referred to as command basis Gross National Product in the US). Although there is no consensus as to the ideal method for computing the terms of trade adjustment (see the debate in Geary 1961 or the range of recommendations given in the UN SNA93 in paragraphs 16.152 to 16.156; our adjustment was recommended by Rasmusen 1960 and Hamada and Iwata 1984), many countries follow Nicholson (1959) and use an import price index to deflate nominal exports. This alternative approach would yield the expression

$$\omega_X^E \left(\frac{dP_X}{P_X} - \frac{dP_M}{P_M} \right),$$

which is equivalent to our adjustment only when trade is balanced. The fourth and final term corresponds to the change in income from net foreign assets, as well as to changes in the net foreign assets position[2].

3.B Aggregate and Industry Level Solow Residuals

The previous subsection showed that the change in welfare is related to a measure of the change in TFP calculated by subtracting factor-share-weighted input growth from the growth in GDP. We refer to this measure as TFP_1. In practice, the capital share of income is

[2] It is possible to derive an equivalent expression with TFP measured using gross national income (GNI) growth, subtracting factor growth weighted by shares in GNI.

diffcult to measure due to the possible presence of fixed costs and pure profits. As a result, the large falls in TFP observed during most emerging market financial crises have been measured using a version of Solow's (1957) residual in which the capital share is approximated by the non-labor share of income

$$\frac{dTFP_2}{TFP_2} = \frac{dV}{V} - \left(1 - \omega_L^V\right)\frac{dK}{K} - \omega_L^V \frac{dL}{L}, \tag{11}$$

which we denote TFP_2.

To connect our aggregate measures of TFP with our industry and plants level discussion of technology growth, note that aggregate value added (or GDP) is simply the sum of value added in each industry j

$$P_V V = \sum_j P_{V_j} V_j,$$

and hence the growth rate of real GDP is given by the value added weighted average growth rates of industry value added

$$\frac{dV}{V} = \sum_j \frac{P_{V_j} V_j}{P_V V} \frac{dV_j}{V_j}.$$

To compute the aggregate Solow residual, we will need to subtract aggregate factor share weighted averages of aggregate inputs. For labor, note that

$$\omega_L^V \frac{dL}{L} = \sum_j \omega_j^V \omega_{Lj}^V \frac{dL_j}{L_j},$$

where ω_j^V is industry j's share of aggregate value added. For capital, the measurement issues surrounding the capital share lead to a more complicated relationship

$$\begin{aligned}
\left(1 - \omega_L^V\right)\frac{dK}{K} &= \sum_j \omega_j^V \left(1 - \omega_{Lj}^V\right) \frac{P_K K_j}{P_K K} \frac{P_V V - P_L L}{P_V V_j - P_L L_j} \frac{dK_j}{K_j} \\
&= \sum_j \omega_j^V \left(1 - \omega_{Lj}^V\right) \frac{\bar{\mu}}{\mu_j} \frac{dK_j}{K_j},
\end{aligned}$$

where

$$\bar{\mu} = \frac{P_V V - P_L L}{P_K K}.$$

Hence, in general, the aggregate Solow residual is given by

$$\frac{dTFP_2}{TFP_2} = \sum_j \omega_j^V \left(\frac{dV_j}{V_j} - \left(1 - \omega_{Lj}^V\right) \frac{\bar{\mu}}{\mu_j} \frac{dK_j}{K_j} - \omega_{Lj}^V \frac{dL_j}{L_j} \right),$$

which is the value added weighted average of the growth in industry Solow residuals adjusted for the capital share measurement issues discussed above[3].

Finally, to connect with industry and firm level data, which is presented in terms of gross output, and our aggregate data using value added, note that the definition of value added implies that

$$\frac{dY_j}{Y_j} = \frac{P_{V_j} V_j}{P_{Y_j} Y_j} \frac{dV_j}{V_j} + \frac{P_Q Q_j}{P_{Y_j} Y_j} \frac{dQ_j}{Q_j} = \omega_{Vj}^Y \frac{dV_j}{V_j} + \omega_{Qj}^Y \frac{dQ_j}{Q_j}. \tag{12}$$

Hence we can rewrite our expression for the growth rate of the aggregate Solow residual as

$$\frac{dTFP_2}{TFP_2} = \frac{1}{\omega_V^Y} \sum_j \omega_j^Y \left\{ \frac{dY_j}{Y_j} - \left(1 - \omega_{Lj}^V\right) \omega_{Vj}^Y \frac{\bar{\mu}}{\mu_j} \frac{dK_j}{K_j} - \omega_{Lj}^Y \frac{dL_j}{L_j} - \omega_{Qj}^Y \frac{dQ_j}{Q_j} \right\}. \tag{13}$$

3.C Industry Productivity and Plant Technology

Next, we study the relationship between the change in technology that affects the productivity of individual plants, and industry level estimates of TFP. Starting with the definition of industry gross output (5), we can use the form of the plant production function and our formulae for the allocation of factors across plants (7) to find an expression for industry output as a function of industry factor usage

$$Y = \Phi A \left[K_P^\alpha L^\beta Q^{1-\alpha-\beta} \right]^\gamma N^{*1-\gamma}, \tag{14}$$

[3] If $P_K K_j = P_V V_j - P_L L_j$, then this expression reduces to the value added weighted growth rate of industry Solow residuals

$$\frac{dTFP_1}{TFP_1} = \sum_j \omega_j^V \left(\frac{dV_j}{V_j} - \left(1 - \omega_{Lj}^V\right) \frac{dK_j}{K_j} - \omega_{Lj}^V \frac{dL_j}{L_j} \right),$$

where

$$\Phi = \sum_i \pi_i \left\{ (1-\tau_{Ai}) \left(\frac{(1-\tau_{Ki})(1-\tau_i)}{\sum_i \pi_i (1-\tau_{Ki})(1-\tau_i)} \right)^{\alpha\gamma} \left(\frac{(1-\tau_{Li})(1-\tau_i)}{\sum_i \pi_i (1-\tau_{Li})(1-\tau_i)} \right)^{\beta\gamma} \times \left(\frac{(1-\tau_{Qi})(1-\tau_i)}{\sum_i \pi_i (1-\tau_{Qi})(1-\tau_i)} \right)^{(1-\alpha-\beta)\gamma} \right\}, \tag{15}$$

captures the effect of the wedges on the allocation of resources and its impact on aggregate productivity, and where K_P denotes the total amount of capital employed in production, but not including the fixed cost paid by each plant.

The above expression depends upon the number of firms in an industry, which is endogenous. Rearranging the free entry condition (4) we find that the number of firms in an industry is a linear function of industry output of the form $N^* = \Lambda Y$ where

$$\Lambda \equiv \frac{1-\gamma}{P_K F / P_Y} \sum_i \pi_i \frac{1}{(1-\tau_{Fi})(1-\tau_{Ki})}.$$

This expression is quite intuitive: if fixed costs $P_K F / P_Y$ are large, or returns to scale are close to constant ($\gamma \simeq 0$), it is optimal for only a small number of plants to produce, and the number of plants does not vary with output.

Substituting this expression in (14) and rearranging yields

$$Y = \left(A \Phi \Lambda^{(1-\gamma)} \right)^{1/\gamma} K^{\alpha} L^{\beta} Q^{1-\alpha-\beta}. \tag{16}$$

Equation (16) shows that, if we know the output elasticities α and β, and calculate industry TFP (denoted TFP_3 which varies by industry) by subtracting output elasticity weighted factor growth from growth in gross output, the result would be a combination of the true technology growth (dA/A) in that industry, plus the effect of changes in the efficiency of the resource allocation mechanism ($d\Phi/\Phi$) plus changes in efficiency with which the number of

firms varies ($d\Lambda/\Lambda$)

$$\begin{aligned}\frac{dTFP_3}{TFP_3} &\equiv \frac{dY}{Y} - \alpha\frac{dK}{K} + \beta\frac{dL}{L} + (1-\alpha-\beta)\frac{dQ}{Q} \\ &= \frac{1}{\gamma}\left[\frac{dA}{A} + \frac{d\Phi}{\Phi} + (1-\gamma)\frac{d\Lambda}{\Lambda}\right].\end{aligned}$$

To illustrate the role of allocative inefficency in reducing industry TFP, differentiate 15 with respect to time to show that changes in Φ come from both the effect of reallocation between existing plant types, which we denote by

$$\begin{aligned}R_1 &= \sum_i \frac{\pi_i^* Y_i}{\overline{Y}}\frac{d(1-\tau_{Ai})}{(1-\tau_{Ai})} + \alpha\gamma\sum_i \pi_i\left(\frac{Y_i}{\overline{Y}} - \frac{K_i}{\overline{K}}\right)\left(\frac{d(1-\tau_i)}{(1-\tau_i)} + \frac{d(1-\tau_{K_i})}{(1-\tau_{K_i})}\right) \\ &+\beta\gamma\sum_i \pi_i\left(\frac{Y_i}{\overline{Y}} - \frac{L_i}{\overline{L}}\right)\left(\frac{d(1-\tau_i)}{(1-\tau_i)} + \frac{d(1-\tau_{L_i})}{(1-\tau_{L_i})}\right) \\ &+(1-\alpha-\beta)\gamma\sum_i \pi_i\left(\frac{Y_i}{\overline{Y}} - \frac{Q_i}{\overline{Q}}\right)\left(\frac{d(1-\tau_i)}{(1-\tau_i)} + \frac{d(1-\tau_{Q_i})}{(1-\tau_{Q_i})}\right),\end{aligned}$$

as well as changes in the composition of plant types, which we denote by

$$R_2 = \sum_i \pi_i\left(\frac{Y_i}{\overline{Y}} - \alpha\gamma\frac{K_i}{\overline{K}} - \beta\gamma\frac{L_i}{\overline{L}} - (1-\alpha-\beta)\gamma\frac{Q_i}{\overline{Q}}\right)\frac{d\pi_i^*}{\pi_i^*}.$$

To understand R_1, it is useful to consider a number of thought experiments. First, suppose that there are no factor distortions, so that at each plant all factor ratios equal the output ratio, and

$$R_1 = \sum_i \pi_i\frac{Y_i}{\overline{Y}}\frac{d(1-\tau_{Ai})}{(1-\tau_{Ai})}.$$

If all plants start with the same technology level ($\tau_{Ai} = 0$ for all i) so that all firms are of the same size ($Y_i = \overline{Y}$), and there is a mean preserving spread in the distribution of τ_{Ai}'s, there is no effect on industry TFP. If, howvere, some plants begin with different TFP levels, the effect of a mean preserving change in the distribution of τ_{Ai}'s depends on whether the variance of the distribution of productivities increases (in which case the most efficient plants, $Y_i > \overline{Y}$, become more productive $d(1-\tau_{Ai}) > 0$ so that$R_1 > 0$) in which case productivity rises, or the variance decreases (the least efficient plants, $Y_i < \overline{Y}$, become more productive

$d(1-\tau_{Ai}) > 0$ so that $R_1 < 0$) in which case productivity falls. In other words, there is a tendency for *increases in the variance of productivity levels to increase aggregate productivity* as production is allocated towards the most efficient plants.

Second, suppose that all plants have the same scale ($\tau_{Ai} = \tau_i = 0$ for all i), but that there are relative factor price distortions. This places a strong restriction on relative movements in the wedges on each factor, and so for simplicity we assume that the wedges on L are unchanged at zero and examine changes in the wedges on intermediate inputs and capital. Then we must have

$$\frac{d(1-\tau_{K_i})}{(1-\tau_{K_i})} = \frac{-(1-\alpha-\beta)}{\alpha}\frac{d(1-\tau_{Q_i})}{(1-\tau_{Q_i})}.$$

so that

$$R_1 = (1-\alpha-\beta)\gamma\sum_i \pi_i\left(\frac{K_i}{\overline{K}} - \frac{Q_i}{\overline{Q}}\right)\frac{d(1-\tau_{Q_i})}{(1-\tau_{Q_i})}.$$

In this case, the largest users of intermediate inputs are also the smallest users of capital, and vice versa. If the variance of the distribution of wedges on intermediate inputs increases, then $d(1-\tau_{Q_i}) > 0$ for plants with $K_i/\overline{K} - Q_i/\overline{Q} < 0$ and industry productivity falls. This result holds more generally, allowing us to conclude that there is a tendency for *increases in the variance of factor wedges to decreas aggregate productivity.*

To understand R_2, note that by definition, $\sum_i d\pi_i^* = 0$, and so if all plant were identical $R_2 = 0$. When there is heterogeneity, however, everything else equal, an increase in the share of types producing above average amount of output increases productivity ($R_2 > 0$) as this represents an increase in the share of the most productive plants. Conversely, everything else equal, an increase in the share of the largest factor users reduces productivity ($R_2 < 0$) as this represents an increase in the most distorted plants.

Next, consider

$$\frac{d\Lambda}{\Lambda} = \frac{dP_Y}{P_Y} - \frac{dP_K}{P_K} + \sum_i\left(\frac{d\pi_i}{\pi_i} - \frac{d(1-\tau_{Fi})}{(1-\tau_{Fi})} - \frac{d(1-\tau_{Ki})}{(1-\tau_{Ki})}\right)\frac{\pi_i}{(1-\tau_{Fi})(1-\tau_{Ki})},$$

which captures the effect of changes in the number of plants on industry productivity. If the price of capital rises faster than the price of output, fixed costs rise, and variations in output

are met with smaller changes in the number of plants and larger increases in incumbent plant production, which reduces industry productivity because of decreasing returns. On the other hand, if fixed costs fall, or there is a shift in the distribution of plants towards those with lower fixed costs, productivity is increased.

Finally, we must allow for the fact that we typically cannot distinguish between an increase in total capital from an increase in capital used in production. Combining the definition of aggregate capital with the free entry condition (4) and the plant's first order condition in capital services from (3) yields the relationship between capital and capital in production in an industry as

$$K = \left(1 + \Lambda \frac{P_K F}{P_Y} \frac{1}{\alpha\gamma} \frac{\sum_i \pi_i (1-\tau_i)}{\sum_i \pi_i (1-\tau_i)(1-\tau_{Ki})}\right) K_P \equiv (1+\Lambda\Gamma) K_P \equiv \kappa K_P, \tag{17}$$

so that

$$\frac{dK}{K} = \frac{dK_P}{K_P} + \frac{d\kappa}{\kappa}.$$

That is, total capital demand will grow faster than total capital used in production if either more firms enter at lower scale ($d\Lambda/\Lambda > 0$) or if there is a relative reduction in the use of capital per unit of otput produced ($d\Gamma/\Gamma > 0$).

3.D Aggregate Productivity and Reallocation Across Industries

In the last two subsections we derived the relationship between the traditional Solow residual and plant level technology. Now we put the pieces together, which allows us also to talk about the effect of reallocation across industries. Substituting for the change in output in (13) by taking the derivative of equation (16), substituting for industry factor shares from (8) and (9), replacing the change in capital used in production by the change in total capital from (17), and rearranging, we obtain that the growth in the Solow residual $dTFP_2/TFP_2$

is given by

$$\frac{1}{\omega_Y^V}\sum_j \omega_Y^j \left\{ \frac{1}{\gamma_j}\frac{dA_j}{A_j} + \frac{1}{\gamma_j}\left(\frac{d\Phi_j}{\Phi_j} + \left(1-\gamma_j\right)\frac{d\Lambda_j}{\Lambda_j}\right) - \alpha_j \frac{d\kappa_j}{\kappa_j} \right. \tag{18}$$
$$+\alpha_j\left(1-\gamma_j\left(1-\bar{\tau}_K\right)\bar{\mu}\right)\frac{dK_j}{K_j} + \beta_j\left(1-\gamma_j\left(1-\overline{\tau}_L\right)\right)\frac{dL_j}{L_j} + \left(1-\alpha_j-\beta_j\right)\left(1-\gamma_j\left(1-\overline{\tau}_Q\right)\right)\frac{dQ_j}{Q_j}$$
$$\left. +\alpha_j\gamma_j\left(\overline{\tau}_{Kj}-\overline{\tau}_K\right)\frac{dK_j}{K_j} + \beta_j\gamma_j\left(\overline{\tau}_{Lj}-\overline{\tau}_L\right)\frac{dL_j}{L_j} + \left(1-\alpha_j-\beta_j\right)\gamma_j\left(\overline{\tau}_{Qj}-\overline{\tau}_Q\right)\frac{dQ_j}{Q_j} \right\},$$

where $\overline{\tau}_K, \overline{\tau}_L$ and $\overline{\tau}_Q$ are the output weighted average wedges on capital, labor and intermediate inputs across industries.

This equation decomposes the change in the traditional Solow residual TFP into five components. The first line of this equation captures three components: a weighted average of industry technology growth; the misallocation within sectors, including any misallocation resulting from entry and exit; and the mismeasurement that results when we use the growth rate of aggregate capital instead of the growth rate of capital used in production. The second line captures the effect of mismeasuring output elasticities in the computation of the Solow residual. The third line is new and captures the misallocation of factors across sectors. To see this, take the example of labor. If, as a result of different wedges in different industries, labor has a higher marginal product in one industry than on average (or $\overline{\tau}_{Lj} > \overline{\tau}_L$) any reallocation of factors to this industry will increase the Solow residual.

Before continuing, it is instructive to examine the corresponding measures of the relationship between the Solow residual, welfare and technological progress in our simple example economies introduced above. In each of these examples, as there is no plant heterogeneity, we abstract from the presence of decreasing returns to scale with a fixed cost of production ($\gamma = 1$ and $F = 0$), and hence also from the distinction between total capital and capital allocated to production.

Example 6 (Continued)**.** *One-Sector Closed Economy Without Frictions*

From equation (18) which relates the Solow residual to growth in technology, we can see that

$$\frac{dTFP_2}{TFP_2} = \frac{dA}{A},$$

which restates the result of Solow (1957). Moreover, as first shown by Weitzman (1976) for the case of linear utility and later shown more generally by Basu and Fernald (2002), our expressions for the change in welfare (10) reduce to

$$\frac{dW}{\lambda P_V V} = \frac{dTFP_1}{TFP_1} = \frac{dA}{A}.$$

Example 7 (Continued)**.** *One-Sector Closed Economy With Imperfect Competition and No Intermediate Inputs*

Relative to the previous example, the only difference is that there is now a wedge between the prices paid by consumers and the marginal cost faced by firms which is given by the mark-up. We represent this in our framework by setting $1 - \tau_{Ki} = 1 - \tau_{Li} = (1+\tau)^{-1}$ *in (18) which yields*

$$\frac{dTFP_2}{TFP_2} = \frac{dA}{A} + \tau(1-\alpha)\left[\frac{dL}{L} - \frac{dK}{K}\right].$$

This can be viewed as a multi-factor analogue of equation (11) in Hall [15]. Likewise for welfare we obtain

$$\frac{dW}{\lambda P_V V} = \frac{dTFP_1}{TFP_1} + \tau\frac{dK}{K} = \frac{dA}{A} + \tau\left[\alpha\frac{dK}{K} + (1-\alpha)\frac{dL}{L}\right]$$

which is the analogue of equations (14) and (28) in Basu and Fernald [5] (with only one sector, the sectoral-reallocation terms are set to zero).

Example 8 (Continued)**.** *Small Open Economy with Imported Intermediate Inputs*

Under the assumptions that K *and* L *are fixed, (18) reduces to*

$$\frac{dTFP_2}{TFP_2} = 0,$$

which is Kehoe and Ruhl's main point: if output is measured ideally, changes in the terms of trade will have no effect on the measured Solow residual. Below we will argue that output is typically not measured ideally (that is, it is not measured using double deflation), and instead

is often measured using what is known as single deflation, for which case we obtain

$$\frac{dTFP_2}{TFP_2} = -\frac{P_M M}{P_V V}\frac{dP_M}{P_M}.$$

This shows that movements in the terms of trade can impact measured Solow residuals, which serves as a counterpoint to the argument in Bajona, Kehoe and Ruhl (2008).

As regards welfare, our equation (10) reduces to

$$\frac{dW}{\lambda P_V V} = \frac{Y}{Y - P_M M}\frac{dY}{Y} - \frac{P_M M}{Y - P_M M}\left(\frac{dP_M}{P_M} + \frac{dM}{M}\right).$$

In the special case where output is Leontieff in primary factors and imported intermediates (here $Q = M$), we know $dY/Y = dM/M$. Moreover, since primary factors are constant, if we assume that there is no change in technology $dY/Y = 0$. Then we have

$$\frac{dW}{\lambda P_V V} = -\frac{P_M M}{P_V V}\frac{dP_M}{P_M}.$$

That is, if the price of imports rises (the terms of trade worsen), welfare falls by an amount proportional to the share of imports in gross domestic product. Interestingly, in this case, measuring the Solow residual from output incorrectly constructed using single deflation leads to a correct estimate of the change in welfare.

Example 9 (Continued)**.** *One-Sector Open Economy Without Frictions*

Next we consider a one-sector open economy without frictions and with unbalanced trade. As for the closed economy version studied above, the relative prices of investment, consumption and output are all fixed at one, and so are the prices of exports and imports. Substituting this into our formulae we obtain

$$\frac{dW}{\lambda P_V V} = \frac{dTFP_1}{TFP_1} + \frac{r_B B}{P_V V}\frac{dr_B}{r_B} = \frac{dA}{A} + \frac{r_B B}{P_V V}\frac{dr_B}{r_B}.$$

Example 10 (Continued)**.** *Two-Sector Open Economy Without Frictions*

In this case,we obtain

$$\frac{dTFP_2}{TFP_2} = \frac{dA}{A},$$

while

$$\frac{dW}{\lambda P_V V} = \frac{dA}{A} + \frac{P_X X}{P_V V}\frac{dP_X}{P_X} - \frac{P_M M}{P_V V}\frac{dP_M}{P_M} + \frac{r_B B}{P_V V}\frac{dr_B}{r_B}.$$

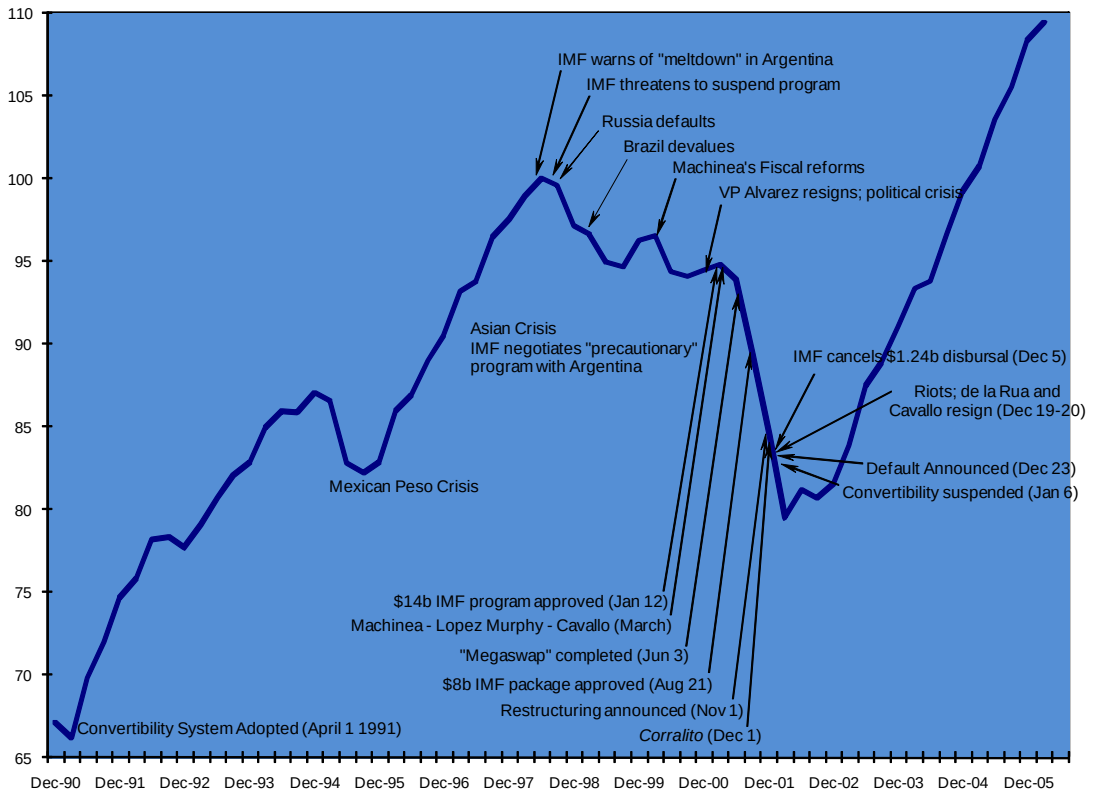
4 Application to Argentina 1997-2002

In this section we describe the application of our framework to one of the largest emerging market financial crises on record: the Argentine crisis of 2001 and 2002. This is a natural case to examine both because of its size and prominence, but also because of the greater availability of data for Argentina than for many other crisis countries. We begin by describing macroeconomic outcomes before turning to plant level data. All data sources are described in more detail in Appendix A.

4.A Output and Productivity

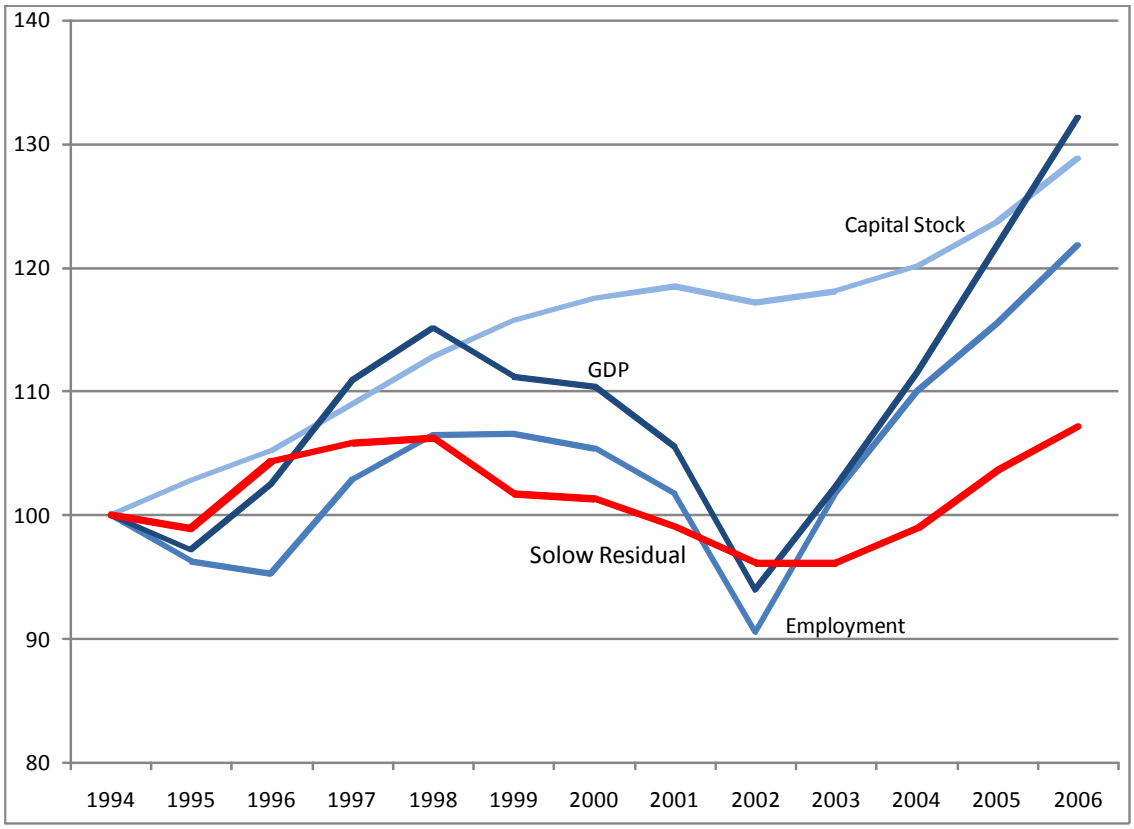
After a decade of relative stability following the end of the hyperinflations of the late eighties and the adoption of a currency board in which the peso was pegged to the US Dollar, Argentina experienced a financial crisis in the years 2001 and 2002. The government engaged in a series of debt restructuring negotiations that ended with the largest sovereign default in history in December 2001. At the same time, there was a currency crisis that wiped out the convertibility regime (the currency board), a banking crisis, and a "sudden stop" in capital inflows.

This period was also associated with a dramatic decline in economic activity, as shown in Figure **??**. Between the peak in the first quarter 1998 and through in the first quarter of 2002, GDP declined by almost 20 per-cent in real terms, with the sharpest declines occurring in the last quarter of 2001 (-5.70%) and the first quarter of 2002 when the quarterly changes in output were -5.7 and -5.0 per-cent respectively.



Timeline of the Argentine Crisis

The magnitude of the decline in output is hard to explain in a growth accounting sense. Figure **??** plots indices of movements in the official measure of the Argentine capital stock and total employment against the level of GDP, as well as the implied level of the Solow residual, with all levels scaled to be equal to 100 in 1994. As shown in the Figure, the capital stock declines modestly in 2002, while the declines in employment are much smaller than the decline in output. As a result, productivity (the Solow residual) falls by about 9 per-cent from its peak in 1998, with roughly six percentage points of this coming in the crisis years of 2001 and 2002.



Agggregate Solow Residual

One possible explanation for this decline in measured productivity is that it is due to declines in factor utilization, which could be particularly severe since we are measuring the number of employees instead of hours worked, and the stock of capital instead of the intensity of its utilization. When we examine the manufacturing sector, for which we have more detailed data, we find that changes in hours worked per-person, or in capacity utilization as measured by changes in power consumption, explain only a part of the movements in productivity. When the crisis hits in 2001, value added and factor utilization decline, but by smaller amounts with a resulting Solow residual fall.[4]

[4] The graph uses unpublised data from INDEC´s Annual Industrial Survey and focuses on surviving firms only.

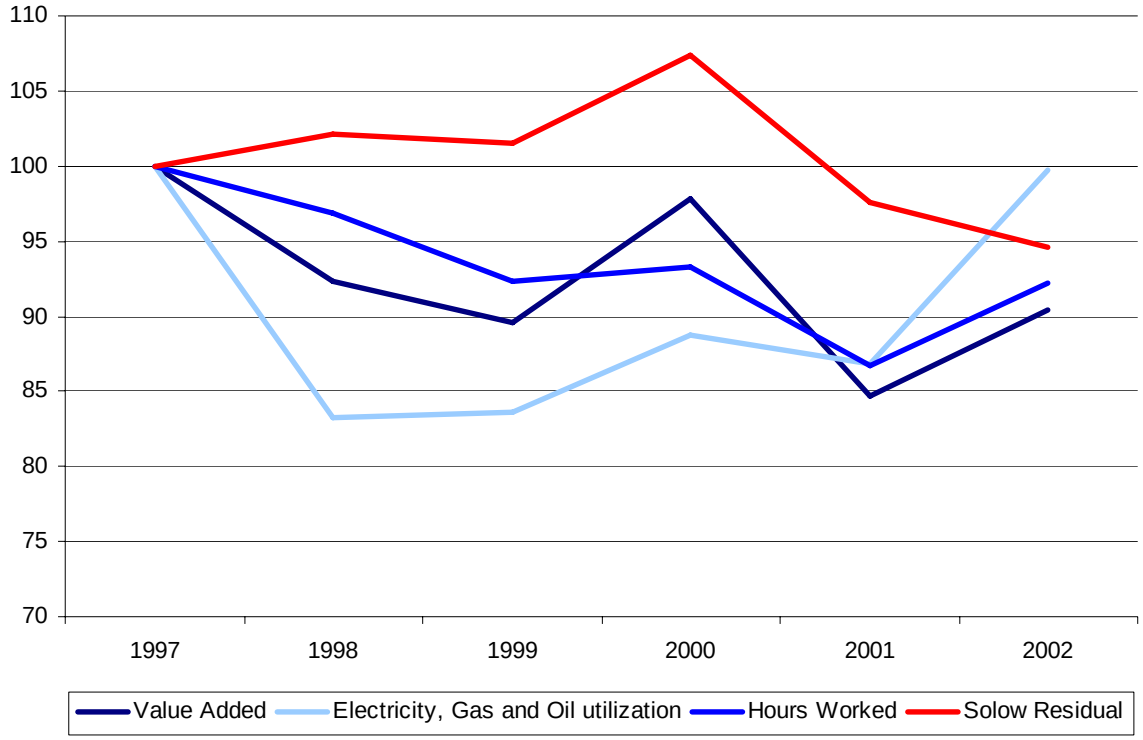


Figure 1: Manufacturing Solow Residual

4.B The Data

Establishment Level Data

In order to analyze the evolution of aggregate productivity and its relation to resource allocation across sectors and plants, we use plant level data from the annual industrial survey (Encuesta Industrial Anual) carried out by the Argentine Institute of Statistics and Census (INDEC). On an annual basis (every March) INDEC conducts a survey of manufacturing plants in the country. The establishments are chosen randomly within each of the 5 digit subsectors in the Central Product Classification of the United Nations. Each establishment, as long as it operates, is followed over time, and disappearing establishments are replaced with the same sampling techniques. New entrants to the survey that have been in existence for more than one year are distinguised from newly opened plants. The survey includes a sample of approximately 4,000 establishments for the period 1996-2002 taken from the universe of establishments with more than 10 workers. The universe of establishments with more than 10 workers constitutes only a small fraction of all establishments in the economy, but it accounts for approximately 80% of employment and more than 80% of output in the manufacturing industry.[5]

[5] Employment in the manufacturing sector accounts for approximately 20% of total employment.

Number of plants and employment by size class, 1993								
Firm size	Number of plants				Employment			
(#N)	Numb plants	Cumul total	Share	Cumul share	Empl	Cumul total	Share	Cumul share
1	26,312	26,312	28	28	26,505	26,505	2	2
2-3	27,738	54,049	30	58	67,385	93,889	6	9
4-5	12,480	66,529	13	71	56,050	149,940	5	14
6-10	11,330	77,859	12	84	87,410	237,350	8	22
11-25	8,711	86,570	9	93	141,984	379,334	13	36
26-40	2,418	88,988	3	96	78,236	457,569	7	43
41-50	880	89,868	1	96	40,589	498,159	4	47
51-150	2,348	92,216	3	99	199,975	698,134	19	66
151-250	441	92,657	0	99	87,123	785,256	8	74
251-400	280	92,937	0	100	89,369	874,625	8	82
401+	219	93,156	0	100	186,903	1,062,528	18	100

(19)

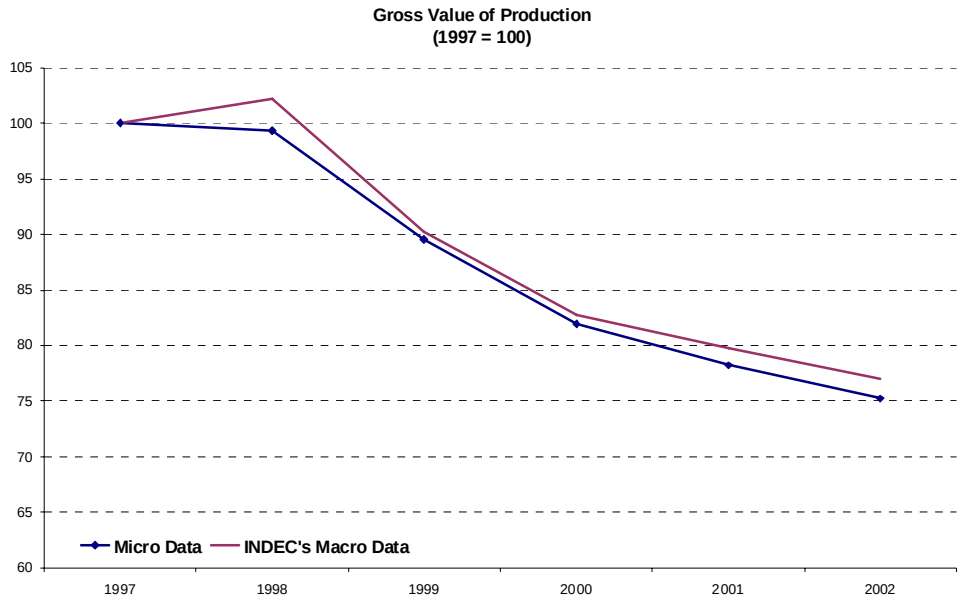
Source: 1994 INDEC's National Economic Census (last available economic census)

The data provided to us by INDEC includes an establishment identifier which allows us to track the performance of each establishment over time. The survey provides information on a range of plant characteristics including the year in which activities began, whether it is the only plant of the firm, foreign ownership (share of foreign capital equal to 0%, between 0% and 10%, more than 10%), and subsector (there are 22 subsectors shown in the Table below). The operational data provided by INDEC includes total wages, total hours worked, cost of inputs, interest payments, expenditures in electricity, gas and other energy sources, total expenditures, total sales in domestic and foreign markets (if any) and investment for each establishment. No balance sheet data are collected, and so we do not have a direct estimate of the plants´ capital stock.

Industries	
15	Food Products and Beverage
16	Tobacco Products
17	Textile Products
18	Clothing Products
19	Leather Products
20	Wood and Cork Products (exc. Furnitures)
21	Pulp and Paper
22	Printing, Editing and Recording Activities
23	Petroleum and Coke (fuel) Products
24	Chemicals Products
25	Rubber and Plastics Products
26	Non-metallic Mineral Products
27	Basic Metals
28	Fabricated Metal Products (exc. Machinery)
29	Mechanical Machinery and Equipment
30	Office Machinery
31	Electrical Machinery and Components
32	Radio, TV and Communication devices
33	Medical, Optical and Precision Instruments.
34	Motor Vehicles and Trailers
35	Other tipe of Transportation Vehicles
36	Furnitures

In order to preserve the anonymity of the respondents, INDEC provided all variables in per worker terms and did not provide us the exact number of workers in each firm. Instead, it provided a size indicator in which plants were classified as "small" if they had less than 80 workers, "medium" with between 80 and 200 workers, and "large" with more than 200 workers. In addition, INDEC included a variable capturing the percentage change in the number of workers. This allows us to capture the evolution of each of the variables of interest. When data needs to be aggregated, we experimented with several methods for imputing firm size including the use of a common size for firms in each category, as well as more sophsticated methods designed to capture the movement of firms between different size categories over time. Our benchmark method works as follows. We assume that each establishment has in 1996 – the first year of our sample – a number of workers equal to the midpoint of its size bin for small and medium firms (45 workers for small firms, 140 for medium size ones). For the following years we compute the number of workers for each establishment using the rate of variation in the number of workers. Whenever this method yielded, for a subsequent year, a number of workers that is inconsistent with the size category reported for that firm, we adjust

the initial number of workers. For large firms that do not change size categories we set their number of workers so that we obtain the aggregate level of employment of firms in the sample from the aggregated data. Except where reported, this method gave similar results to those from more sophisticated procedures. As shown in the next Figure, our benchmark method does an excellent job matching the evolution of manufacturing gross value of production from INDEC´s aggregate manufacturing data.



The restriction to manufacturing plants means that we are unable to analyze the behavior of production units throughout the entire economy. As a result, we will compare our findings with the results for productivity for the manufacturing sector, and will then extrapolate our results for the entire economy. Note that manufaturing represents about one-fifth of the economy in terms of value added, and as shown above the manufacturing sector evolves in a very similar way to the aggregate economy.

4.C Data Limitations

Before we can apply the results of our theoretical analysis above to Argentine data, we need to address a number of additional measurement issues. First of all, we only have plant

level data for the manufacturing sector while in order to measure the effect on welfare we would need for the whole economy. This restriction creates a dichotomy in the way we bring our model to the data. While we focus on manufacturing data in order to analyze the links between resource allocation and productivity, we use aggregate data for the whole economy to study the links between productivity and welfare.

In addition to this dichotomic approach, we face a number of data limitations that we address below.

Capital Services

Our establishment level dataset does not include data on the assets of the plant. Thus we do not have even a book-value estimate of the plants capital stock. To circumvent this difficulty, we assume that capital devoted to production is used to produce *capital services* KS using a Leontieff production function

$$KS_i = \min\left\{E_i, \frac{1}{\theta}K_i\right\},$$

where E_i refers to purchases of *energy*, which is introduced as the $J+1$'th primary commodity, and $1/\theta$ captures the number of units of energy required to power one unit of physical capital. We continue to assume that fixed costs are denominated in terms of capital, and not capital services. Then if the cost of energy and capital rental, and their wedges, are given by P_E, P_K, τ_{Ei}, and τ_{Ki}, respectively, the market price of a unit of capital services is

$$P_{KS} = P_E + \theta P_K,$$

and we can define the wedge on capital services as a whole, τ_{KSi}, so that it satisfies

$$\frac{P_{KS}}{1-\tau_{KSi}} \equiv \frac{P_E}{1-\tau_{Ei}} + \theta\frac{P_K}{1-\tau_{Ki}}.$$

The analysis of the model proceeds almost exactly as above, except in two respects. First, purchases of energy must now be subtracted from gross output to compute value added; we discuss this further below. Second, the relationship between total capital in an industry

K_j, and capital services devoted to production in that industry KS_j is now given by

$$K_j = \frac{P_{KS}}{P_K}\kappa KS_j = \hat{\kappa} KS_j,$$

so that

$$\frac{d\hat{\kappa}}{\hat{\kappa}} = \left(\frac{dP_{KS}}{P_{KS}} - \frac{dP_K}{P_K}\right) + \frac{d\kappa}{\kappa}.$$

Now, if the price of energy rises making the price of capital services rise faster than the price of capital, the ratio of capital to capital services in the industry rises.

Measured GDP

When going from productivity to measured output we might need to do some additional adjustments. In the theory above, movements in real GDP were constructed in equation (12) by taking the growth rate of the value of output, measured in base year prices, and subtracting from this the value of intermediate input growth, also valued at base year prices. In the terminology used by national income statisticians, real value added was constructed using *double deflation* which refers to the fact that prices for *both* output *and* intermediate inputs were held constant. With the addition of energy as an input, this now requires subtracting growth in energy usage valued at base year prices.

As a practical matter, data on prices are both expensive to collect and potentially subject to serious measurement error. This problem is especially severe for developing countries. In such cases the United Nations' System of National Accounts recommends several alternative methods for calculating real value added (see paragraphs 16.68 to 16.70 of the UN SNA93 available at http://unstats.un.org/unsd/sna1993/toctop.asp). One of the most commonly used involves deflating nominal value added by the output price and is hence referred to as *single deflation* in which case real value added is given by

$$V_s^{SD} = P_{Yt}\left(Y_s - \frac{P_{Qs}}{P_{Ys}}Q_s - \frac{P_{Es}}{P_{Ys}}E_s\right) = \sum_m P_{Y_{mt}}\left(Y_{ms} - \frac{P_{Qs}}{P_{Y_{ms}}}Q_{ms} - \frac{P_{Es}}{P_{Y_{ms}}}E_{ms}\right).$$

Another involves approximating movements in real value added with movements in gross

output (the "gross output" method) where

$$V_s^{GO} = \frac{Y_s}{Y_t}\left(P_{Y_t}Y_t - P_{Qt}Q_t - P_{Et}E_t\right) = \sum_m \frac{Y_{ms}}{Y_{mt}}\left(P_{Y_{mt}}Y_{mt} - P_{Qt}Q_{mt} - P_{Et}E_{mt}\right).$$

In the case of Argentina, real gross domestic product is constructed from the production side of the accounts, with real value added by industry constructed using different methods for each industry depending on the data available[6] We approximate this complicated state of affairs by treating gross domestic product data as though it was constructed using single deflation for a subcomponent of the economy denoted SD.

In continuous time in the neighborhood of the base year (and hence ignoring the importance of rebasing), the relationship between Divisia real value added growth, calculated using double deflation (denoted V), and that measured using a mixture of single and double deflation (denoted V^M for "measured"), satisfies

$$\frac{dV^M}{V^M} = \frac{dV}{V} - \frac{P_{V^{SD}}V^{SD}}{P_V V}\left[\frac{P_Q Q^{SD}}{P_{V^{SD}}V^{SD}}\left(\frac{dP_Q}{P_Q} - \frac{dP_{Y^{SD}}}{P_{Y^{SD}}}\right) + \frac{P_E E^{SD}}{P_V V}\left(\frac{dP_E}{P_E} - \frac{dP_{Y^{SD}}}{P_{Y^{SD}}}\right)\right],$$

where we have exploited the fact that in the base year $P_V V = P_{V^M}V^M$. This shows that if intermediate input prices rise at the same rate as output prices, the two measures are equivalent, while if they rise faster[7] the growth rate of real value added will be understated. As a result, if we were to calculate the traditional Solow residual using actual Argentine data, we would obtain a third measure of total factor productivity TFP_3 which is related to the Solow residual TFP_2 studied above by

$$\begin{aligned}\frac{dTFP_3}{TFP_3} &= \frac{dV^M}{V^M} - \left(1 - \frac{P_L L}{P_V V}\right)\frac{dK}{K} - \frac{P_L L}{P_V V}\frac{dL}{L} \\ &= \frac{dTFP_2}{TFP_2} - \frac{P_{V^{SD}}V^{SD}}{P_V V}\left[\frac{P_Q Q^{SD}}{P_{V^{SD}}V^{SD}}\left(\frac{dP_Q}{P_Q} - \frac{dP_{Y^{SD}}}{P_{Y^{SD}}}\right) - \frac{P_E E^{SD}}{P_V V}\left(\frac{dP_E}{P_E} - \frac{dP_{Y^{SD}}}{P_{Y^{SD}}}\right)\right] \quad (20)\end{aligned}$$

[6] See http://www.mecon.gov.ar/secpro/dir_cn/ant/fuentes/mi.htm for details.

[7] This might be expected to be the case during a financial crisis with imported intermediate inputs priced in foreign currency; see Mendoza and Yue [27] for a discussion.

Crises Lasting Multiple Periods

In the analysis above, we assumed that the crisis lasted only one period. As shown above, however, the Argetine crisis was being forecast as early as April 1998 when IMF officials warned of a possible "meltdown". This has no effect on our analysis of the Solow residual above given the assumptions of our model. However, as consumers are forward looking, it will have an impact on the change in welfare. In particular, when we calculate the change in household welfare, we must now take into account the change in tomorrows value function, as well as the change in its value resulting from different accumulation decisions.

This is straightforward to analyze. Replicating the derivations above we find that the change in welfare now includes another term capturing the change in future welfare

$$\begin{aligned}\frac{dW}{\lambda P_V V} &\equiv \frac{\partial W/\partial t}{\lambda P_V V} = \frac{dTFP_1}{TFP_1} + \omega_G^E \left(\frac{\Gamma'(G)}{\lambda P_G} - 1\right)\frac{dG}{G} \\ &\quad + \left(\omega_X^E \frac{dP_X}{P_X} - \omega_M^E \frac{dP_M}{P_M}\right) + \frac{r_B B}{P_V V}\frac{d(r_B B)}{r_B B} + \frac{1}{1+r'_B}\frac{P'_V V'}{P_V V}\frac{\partial W'/\partial t}{\lambda' P'_V V'}.\end{aligned}$$

Hence, writing the growth rate of nominal value added as the product of the rate of inflation π' and the rate of growth of real GDP g' we obtain

$$\frac{1}{1+r'_B}\frac{P'_V V'}{P_V V} = \frac{1+g'}{1+R'_B},$$

where

$$1 + R'_B = \frac{1+r'_B}{1+\pi'}.$$

That is, we can simply iterate on this analysis and accumulate using a growth adjusted real interest rate.

4.D Implementation

In order to bring the production side of the model to the data we need to calibrate the values of the production function parameters. We use aggregate data for Argentina for the year 1997 to compute $\alpha\gamma$ and $\beta\gamma$ (and hence also $(1-\alpha-\beta)\gamma$) for each year under the

assumption that wedges are zero.[8] We assume that the decreasing returns to scale parameter $\gamma = 0.9$, which is in the neighborhood of estimates computed by Atkeson, Khan and Ohanian (1996).

Given estimates of α, β, and γ, we can then use our plant level data at both the firm and industry level to obtain individual wedges and their weighted industry averages. In particular, industry data on factor shares allows us to compute the output weighted industry average wedges on labor and intermediate inputs from

$$\begin{aligned}
\left(1-\bar{\tau}_{Lm}^{Y}\right) &= \frac{1}{\beta_m \gamma_m} \frac{P_L L_m}{P_Y Y_m}, \\
\left(1-\bar{\tau}_{Qm}^{Y}\right) &= \frac{1}{\left(1-\alpha_m-\beta_m\right)\gamma_m} \frac{P_Q Q_m}{P_Y Y_m},
\end{aligned}$$

and a multiple of the capital services wedge

$$\left(1-\bar{\tau}_{KSm}^{Y}\right)\left(1-\frac{\theta P_K}{P_E+\theta P_K}\right)=\frac{1}{\alpha_m \gamma_m}\frac{P_E E_m}{P_Y Y_m}.$$

Plant level wedges can be obtained in a similar way from the equations in (3)above.

For the purposes of calculating the terms in Φ for each sector, however, all we need to do is to compare factor usage at each plant with their average usage in the industry. The only exception are the productivity wedges τ_{Ai}. For this we calculate for each plant

$$A_i = A\left(1-\tau_{Ai}\right) = \frac{Y_i}{\left[KS_i^{\alpha} L_i^{\beta} Q_i^{1-\alpha-\beta}\right]^{\gamma}}.$$

This poses three challenges, with our dataset, as we do not observe directly the stock of capital, the exact number of workers and establishment level output and input prices. We use the employment data discussed above to compute an estimate of hours worked. Estimates of the initial industry level capital stock are combined with data on energy consumption at each plant to estimate the usage of capital services. Movements in energy usage, combined with data on the price of energy from INDEC's wholesale price index (IPIB: *Índice de Precios*

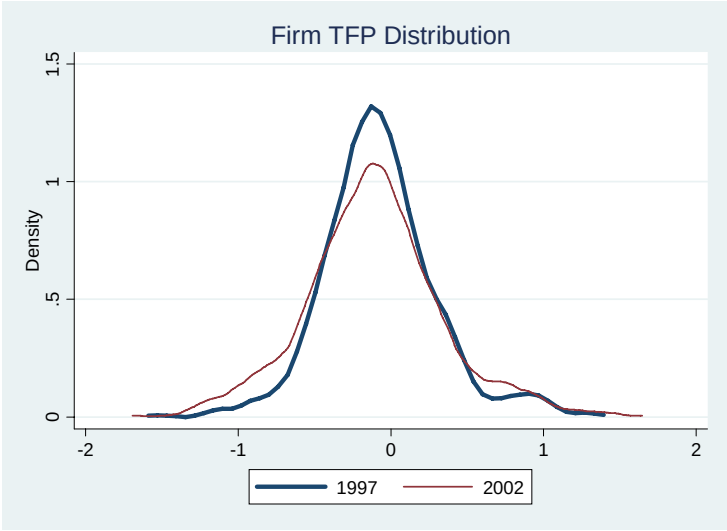
[8] As a robustness check we compute these parameters also using US data. Our results remain essentially unchanged.

Internos Básicos) are used to compute the change in capital services over time.

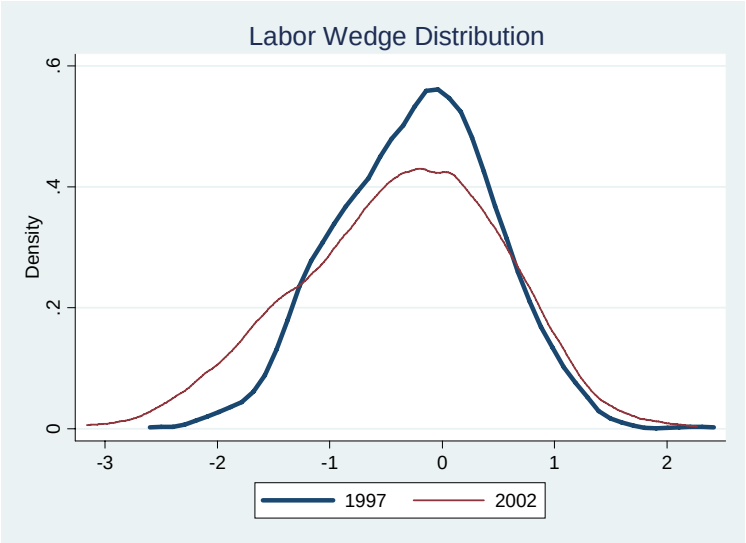
Although we do observe sales and changes in inventories, we do not observe firm specific prices nor output. To recover output from the the value of sales, sales we use average industry prices from IPIB for each manufacturing subsector. To recover intermediate inputs from the variable "cost of inputs", since inputs can be imported or produced domestically, we first obtain the industry shares of imported and domestic inputs using INDEC's input-output matrix from 1997, and then construct an industry average input price from IPIB prices.

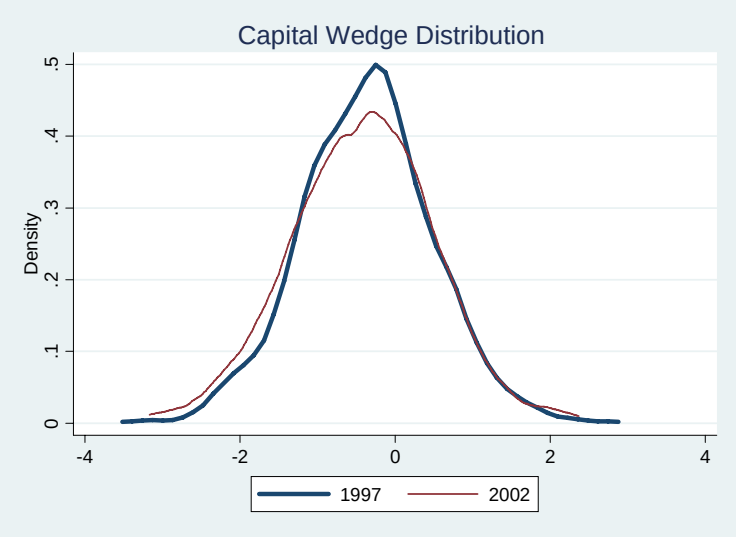
Descriptive Statistics

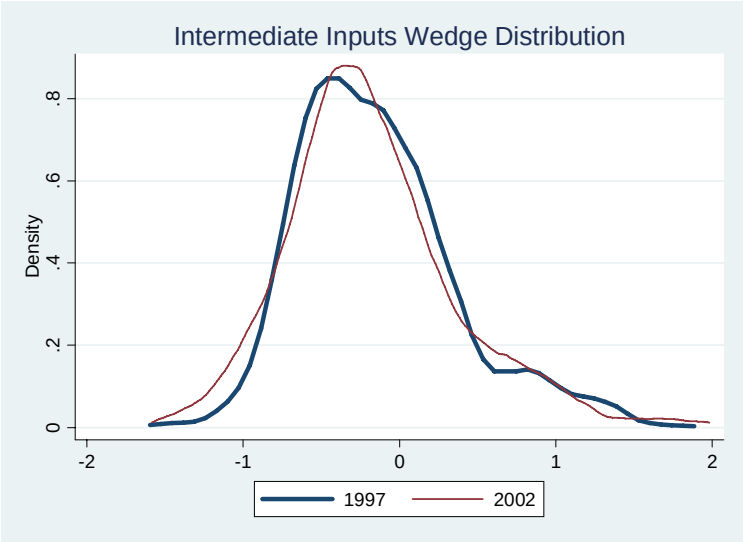
First, we look at the distribution of wedges and productivities for 1997 and for 2002. The following figure shows the distribution of establishments´ productivity as a log-deviation from industry specific means for surviving firms in the sample, after excluding the top and bottom 1% of observations. We observe that in the year of Argentina's financial crisis, 2002, the distribution has fatter tails, particularly the lower one, reflecting a drop in productivity for a large number of firms.



We also observe fatter tails in 2002 than in 1997 for the labor wedges, while for the capital and intermediate inputs wedges the changes are smaller.


Labor Wedge Distribution
Density
0
.2
.4
.6
-3
-2
-1
0
1
2
1997
2002

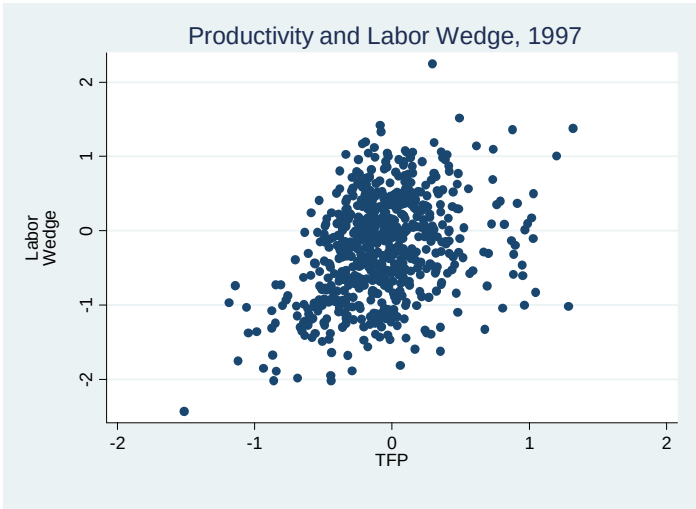

Capital Wedge Distribution
Density
0
.1
.2
.3
.4
.5
-4
-2
0
2
4
1997
2002

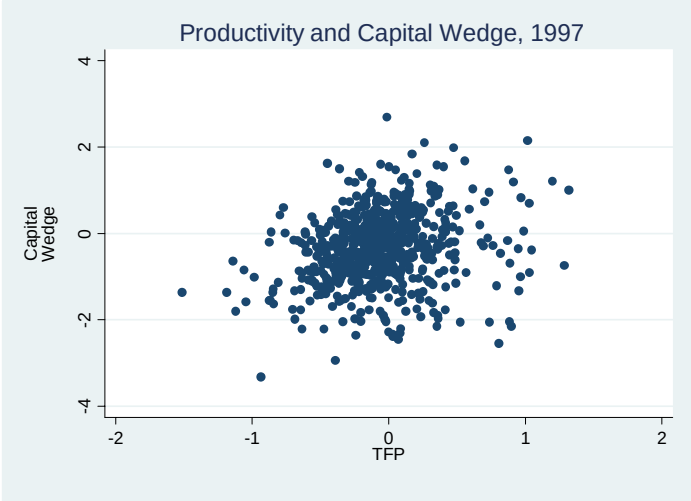


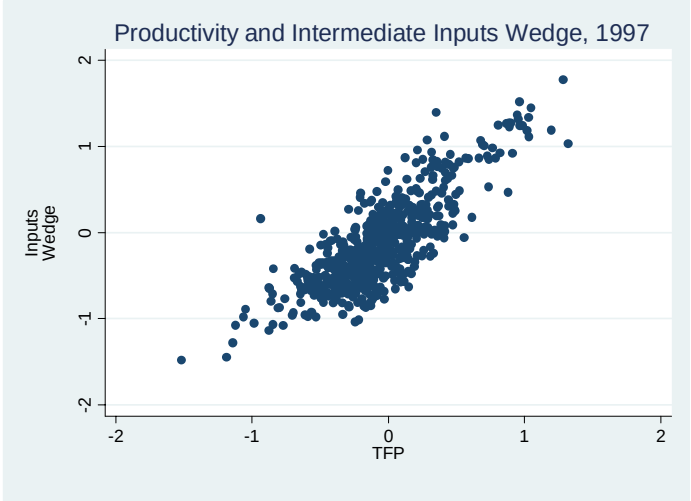
The following table shows some descriptive statistics for the joint distribution of wedges and productivities in Argentina as log-deviations from industry specific means. We observe that the dispersion of TFP, the labor wedge and the intermediate inputs wedge increased by around 23%, 28% and 8%, respectively, between 1997 and 2002 while the dispertion of the capital wedge remained roughly unchanged. The table also shows that TFP is positively correlated with all three wedges and that these correlations became stronger in 2002.

Distribution of wedges and productivity in Argentina				
	A_i	$\frac{1}{(1-\tau_{Li})}$	$\frac{1}{(1-\tau_{Ki})}$	$\frac{1}{(1-\tau_{Qi})}$
			1997	
SD	0.43	0.72	1.35	0.51
90-10	0.85	1.79	2.09	1.18
75-25	0.40	0.95	1.08	0.63
Correlation with A_i	1	0.35	0.22	0.81
			2002	
SD	0.53	0.92	1.36	0.55
90-10	1.07	2.31	2.26	1.37
75-25	0.52	1.22	1.21	0.63
Correlation with A_i	1	0.53	0.34	0.80

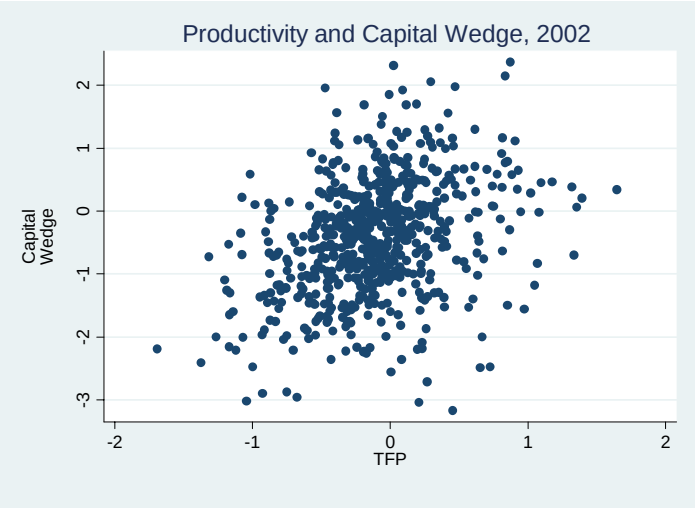
The next figures show scatter plots of the log of the wedges against the log of productivities for the years 1997 and 2002. The figures confirm the patterns described by the statistics in the previous table about correlations and dispersion.

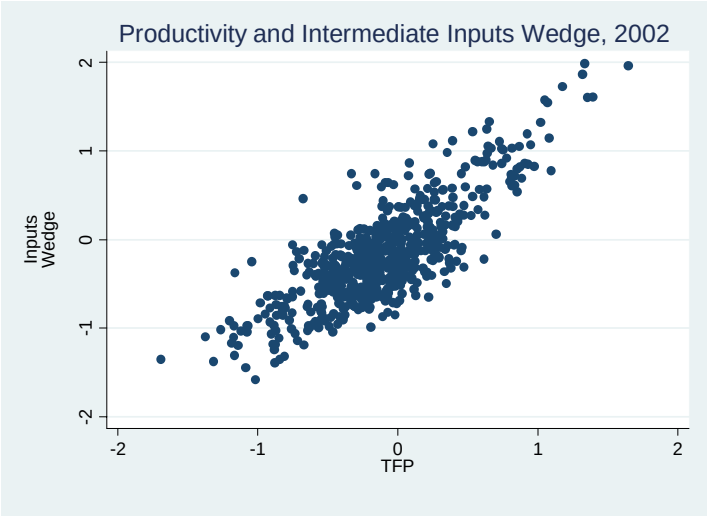



Productivity and Capital Wedge, 1997
Capital Wedge
4
2
0
-2
-4
-2
-1
0
1
2
TFP


Productivity and Intermediate Inputs Wedge, 1997
Inputs Wedge
2
1
0
-1
-2
-2
-1
0
1
2
TFP

Productivity and Labor Wedge, 2002
Labor Wedge
-3
-2
-1
0
1
2
-2
-1
0
1
2
TFP


Productivity and Capital Wedge, 2002
Capital Wedge
-3
-2
-1
0
1
2
-2
-1
0
1
2
TFP



Measuring Productivity and Resource Allocation (Preliminary)

In this section we analyze the role of changes in resource allocation in explaining the decline of almost 23% observed in TFP in the manufacturing sector between 1997 and 2002. In order to do this we implement equation (**??**) that decomposes the change in TFP . The following table summarizes our results (ALL RESULTS IN THIS SECTION ARE PRELIMINARY).

	% of change 2002 vs 1997
Manufacturing TFP	-13.8
Efficiency of resource allocation across industries	-5.0
Efficiency of resource allocation within industries	-1.1
Residual (technology and other mismeasurements)	-7.7

Our main finding is that the change in the efficiency of resource allocation explains approximately half of the decline one third of the decline in TFP. In particular, the decline in the efficiency of resource allocation across sectors explains half of the decline in manufacturing TFP.

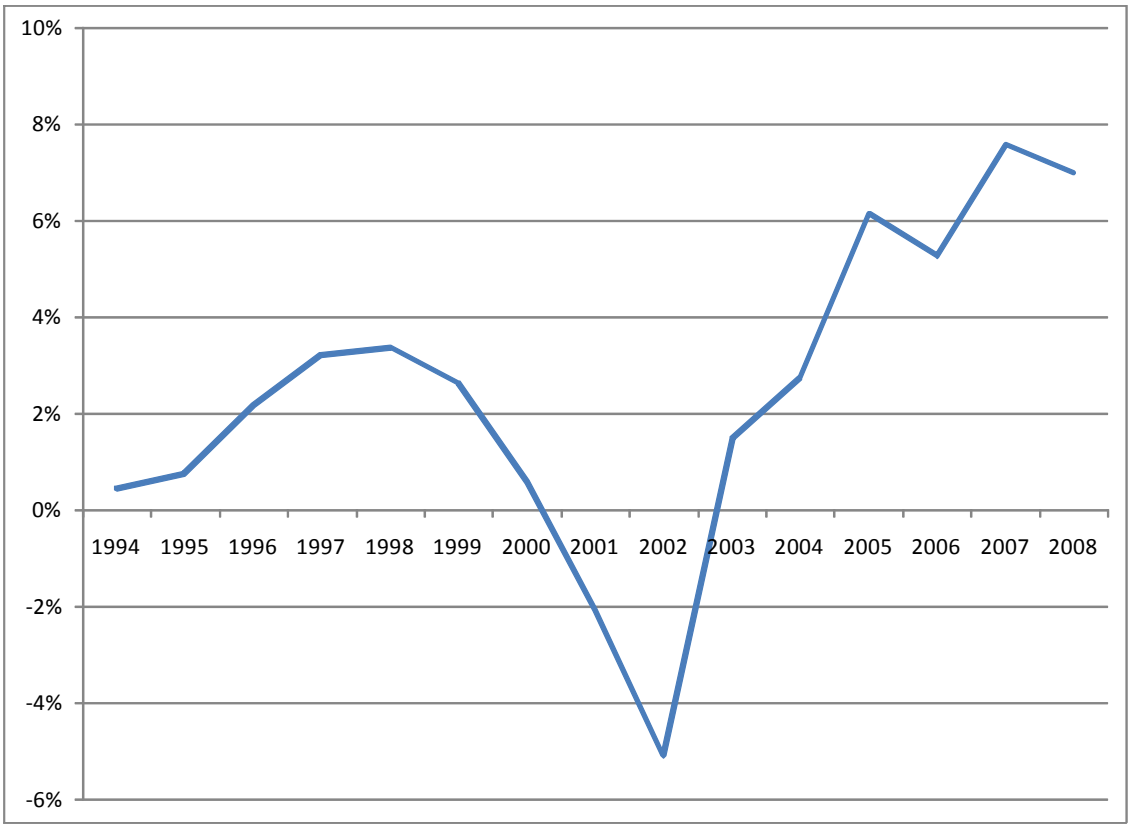
4.E Welfare

The decline in welafare in Argentina between 1997 and 2002 was approximately 8%. As shown in equation **??**, the change in Argentine welfare can be decomposed in the changes in TFP adjusted for single deflation, factor shares mismeasurement, terms of trade and net factor income from abroad effects and the effect of wasteful government spending. In this subsection, we explore each of these factors in turn.

First, we consider the role of movements in the terms of trade. Intuitively, if the terms of trade deteriorate, the country must pay more for its imports relative to what it receives for its exports, and so has less real income to spend. In the equation, this is represented by adjusting for the change in export and import prices each weighted by their shares in gross domestic product. From 1993 to 2002 both exports and imports averaged close to 8% of gross domestic product. Being a relatively closed economy during the period, the changes in terms of trade had only a minor effect on welfare (-0.2%).

Second, we examine changes in net factor payments, and in particular those payments made on foreign investments. Over the period 1993 to 2002, these payments averaged -2.3% of gross domestic product. Even after adjusting the balance of payments for the effect of the 2001 sovereign default, factor payments to the rest of the world increased when measured in ARS as a result of the devaluation and contributed by -2.8 percentage points to the decline in welfare.

Third, we examine the role of changes in government expenditure. As noted above, if the government changes expenditure optimally, this term plays no role in the welfare calculations. The reason is that it is enough to measure the change in the countries ability to produce resource, since if resources are spent efficiently, each use has the same benefit on the margin. If, however, one believes that government spending is purely wasteful, any decrease in government spending is welfare improving and this is what happened in 2001 and 2002. Figure **??** plots growth in the real level of government consumption expenditure throughout the crisis. As might be expected, given the fiscal issues facing Argentine governments, government spending grew strongly in most years, although it fell in both 2001 and 2002, and in the latter year by roughly 5 per-cent.

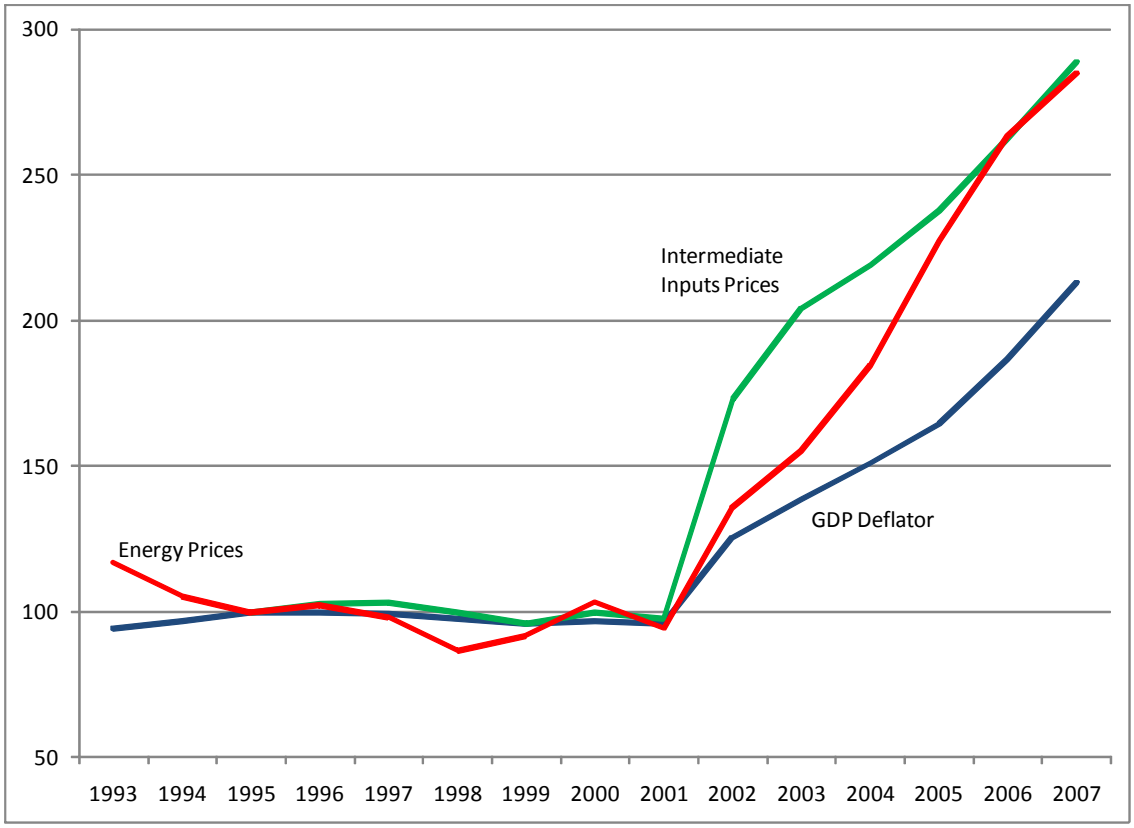


Growth in Real Government Consumption

Finally, we measure the role of mismeasurement in affecting the relationship between aggregate productivity and welfare.[9] As we saw above, mismeasurement may occur for one of two reasons. First, growth in real value added will be mismeasured whenever it is calculated using single deflation and whenever the growth in the relative price of output is less than the growth in intermediate input or energy prices. As Argentina imports many intermediate inputs, it is expected that these prices will have risen significantly throughout the crisis. This is confirmed in Figure **??** which plots movements in both energy prices and intermediate inputs prices throughout the crisis. As shown in the Figure, prior to the crisis, intermediate input prices tracked the GDP deflator quite closely. Energy prices were far more volatile than the GDP deflator, sometimes fluctuating by more than 20 per-cent, but on average mirrors the GDP deflator. After the crisis, all prices rose dramatically, although

[9] Note that our discussion in the previous section was focused on the manufacturing sector only for which we had micro data. The decline in manufacturing TFP doubled the measured decline in aggregate TFP.

both intermediate input prices and energy prices increased much faster In 2002, intermediate input prices increased almost forty per-cent faster than the GDP deflator, peaking at 47 per-cent higher in 2003. The relative price of energy to output rose faster in the years following the crisis, but even in 2002 was 8 per-cent higher than before the crisis. We estimate that 25 per-cent of the Argentine economy, by value added, is measured using single deflation.



Intermediate Input Prices

The second source of mismeasurement comes from our construction of the Solow residual using weights that did not correctly capture the true social cost of supplying factors of production. In particular, if there are pure profits, the residual of value added after subtracting payments to labor need not equal the sum of returns to capital. To measure these terms, we apply our model to data from the United States in which we assume firms face zero wedges in their factor hiring decisions. This allows us to recover labor shares by industry directly, and using data on energy purchases as a share of gross output, also an estimate for

the share of capital services.

The results for each of these components, as well as their aggregate effect on welfare, are presented in Table 4.E.

Table : The Change in Welfare and its Components against 1997

Year		1998	1999	2000	2001	2002
Productivity	Measured Solow Residual	0.4	-4.0	-4.5	-6.6	-9.1
Mismeasurement	Solow Residual Adjusted by Single Deflation	0.1	−4.4	−4.5	−6.7	−4.6
	Factor Elasticities	0.2	0.4	0.5	0.6	0.5
Foreign Trade	Goods	−0.4	−0.8	−0.2	−0.2	−0.2
	Factors	−0.5	−0.5	−0.5	−0.6	−2.8
Government	Wasteful	0.5	0.8	0.3	0.0	0.9
Welfare	Benevolent G	−0.5	−5.3	−4.6	−6.9	−7.1
	Wasteful G	−0.1	−4.5	−4.3	−6.9	−8.0

As shown in the appendix, when the shock that hits the economy has effects that last over several periods, it is necessary to aggregate disocunted values of these year-by-year welfare costs to compute the overall welfare cost. Assuming that the economy returned to normal in 2003, and using a five percent discount rate, with a benevolent government Argentine welfare fell by 14.5 per-cent as a result of the crisis. With a wasteful government, Argentine welfare fell by 16.6 per-cent. This is almost certainly an underestimate of the costs of the crisis, since the sovereign default has still not been fully resolved as of this writing, access to international capital markets remains limited and most importantly we are abstracting in our analysis from the effects of unvoluntary unemployment.

5 Conclusions

Financial crises in emerging market economies appear to be very costly. In this paper, we presented a theoretically consistent methodology for calculating the welfare costs of a crisis (or any economic shock) on a small open economy and for decomposing these welfare costs into the effect of changes in the terms of trade, the terms of foreign investments, changes in government spending, and changes in an economies productive capacity. We use the framework also to measure the impact of changes in the efficiency of the resource allocation mechanism in productive capacity.

We then applied this methodology to Argentina for the 2001 – 2002 financial crisis using a mixture of aggregate data, and plant level data drawn from a unique dataset. We found that welfare fell by almost 15 per-cent in a cummulative basis as a result of the crisis, with the largest effect coming from a decline in productivity. . Focusing on the manufacturing sector due to data availability, we show that of the decline in productivity, more than half can be explained by a decline in the efficiency of the resource allocation mechanism which shows up with an increasingly poor allocation of factors across plants as the crisis progresses.

Our framework can applied in a number of areas. Focusing on the measurement of welfare changes, an advantage of our framework is that it provides a single theoretically consistent measure of welfare change that is related to, but distinct from, measures currently in use for measuring real national income and total factor productivity. Thus, it allows researchers to replace the patchwork collection of facts that usually passes for a quantification of the social costs of crises. Applying this measure to a wide range of crises also holds out the promise of being able to identify the types of crises, and their features, that are most important in affecting welfare. For example, we may be able to ascertain whether sovereign defaults are, on average, more costly that currency crises, and whether this works primarily through changes in the terms of trade, or changes in the ability of the economy to produce output.

To the extent that changes in the efficiency of the resource allocation mechanism prove to be the most important channel, this begs the question of the precise mechanism by which a crisis affects the allocation. It seems plausible that financial crises, which often result in severe disruption of the domestic financial sector, would lead to a decline in the efficiency

with which financial intermediation occurs. It also seems plausible that, to the extent to which credit mechanisms are important in facilitating exchange, a decline in the efficiency of financial intermediate may lead to a deterioration in the operation of labor markets (through the availability of working capital, as in Neumeyer and Perri 2004) or intermediate input markets (as in Mendoza and Yue 2008). In future work, we plan to study the details of the evolution of the wedges computed above with a view to discriminating between these different mechanisms.

References

[1] Arellano, Cristina and Enrique Mendoza. 2003. "Credit Frictions and 'Sudden Stops' in Small Open Economies: An Equilibrium Business Cycle Framework for Emerging Markets Crises." in *Dynamic Macroeconomic Analysis: Theory and Policy in General Equilibrium* S. Altug, J. Chadha and C. Nolan (Eds.) Cambridge U. Press, 8880.

[2] Backus, David K., Patrick J. Kehoe, and Finn E. Kydland. 1992. "International Real Business Cycles." *The Journal of Political Economy*, 100:4, pp. 745-75.

[3] Backus, David K., Patrick J. Kehoe, and Finn E. Kydland. 1994. "Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?" *The American Economic Review*, 84:1, pp. 84-103.

[4] Baily, M.N., Hulten, C., Campbell, D. 1992. "Productivity dynamics in manufacturing plants." *Brookings Papers on Economic Activity (Microeconomics)* 1, 187–267.

[5] Basu, Susanto and John G. Fernald. 2002. "Aggregate Productivity and Aggregate Technology." *European Economic Review*, 46:6, pp. 963-91.

[6] Baxter, Marianne and Mario J. Crucini. 1995. "Business Cycles and the Asset Structure of Foreign Trade." *International Economic Review*, 36:4, pp. 821-54.

[7] Benjamin, David and Felipe Meza. 2007. "Total Factor Productivity and Labor Reallocation: the Case of the Korean 1997 Crisis." University of Southhampton Working Paper.

[8] Bhutta, Zulfiqar A., Fauzia Ahmad Bawany, Asher Feroze, and Arjumand Rizvi. 2008. "The Impact of the Food and Economic Crisis on Child Health and Nutrition." UNICEF Working Paper.

[9] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan. 2005. "Sudden Stops and Output Drops." *American Economic Review*, 95:2, pp. 381-87.

[10] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan. 2006. "Business Cycle Accounting." Federal Reserve Bank of Minneapolis Staff Report, 328.

[11] Christiano, Lawrence J., Christopher Gust, and Jorge Roldos. 2004. "Monetary policy in a financial crisis." *Journal of Economic Theory*, 119:1, pp. 64-103.

[12] Domar, E.D. 1961. "On the measurement of technical change." *Economic Journal* 71, 710–729.

[13] Foster, Lucia., John Haltiwanger and C.J. Krizan. 2001. "Aggregate Productivity Growth: Lessons From Microeconomic Evidence." in Edward Dean, Michael Harper and Charles Hulten (Eds). *New Developments in Productivity Analysis.*

[14] Geary, R. C. (1961) "Problems in the Deflation of National Accounts: Introduction", *Review of Income and Wealth*, series 9, 1961.

[15] Hall, Robert E. 1988. "The Relation between Price and Marginal Cost in U.S. Industry." *The Journal of Political Economy*, 96:5, pp. 921-47.

[16] Hall, Robert E. 1990. "Invariance properties of Solow's productivity residual." In: Diamond, P. (Ed.), *Growth, Productivity, Employment.* MIT Press, Cambridge, MA.

[17] Hamada, Koichi and Iwata, Kazumasa (1984) "National Income, Terms of Trade and Economic Welfare" *The Economic Journal*, 94 (376) pp. 175-171.

[18] Hsieh, Chang-Tai and Peter J. Klenow. 2007. "Misallocation and Manufacturing TFP in China and India." National Bureau of Economic Research, Inc.

[19] Hulten, C., 1978. "Growth accounting with intermediate inputs." *Review of Economic Studies* 45, 511–518.

[20] Kehoe, Timothy J. and Kim J. Ruhl. 2006. "Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate" Unpublished Paper, University of Minnesota.

[21] Kehoe, Timothy J. and Kim J. Ruhl. 2008. "Are shocks to the terms of trade, shocks to productivity?" Unpublished paper, Federal Reserve Bank of Minneapolis.

[22] Knowles, James C., Ernesto M. Pernia, and Mary Racelis. 1999. "Social Conseuqences of the Financial Crisis in Asia." Asian Development Bank Staff Paper, 60.

[23] Lee, Joung-Woo. 2004. "Social Impacts of the Crisis," in *The Korean Economy Beyond the Crisis*. D.-K. Chung and Barry Eichengreen eds. Cheltenham: Edward Elgar.

[24] Meza, Felipe and Erwan Quintin. 2005. "Financial Crises and Total Factor Productivity." Center for Latin American Economics Working Paper, 0105.

[25] Mendoza, Enrique. 2006. "Endogenous Sudden Stops in a Business Cycle Model with Collateral Constraints: A Fisherian Deflation of Tobin's Q." University of Maryland Working Paper.

[26] Mendoza, Enrique and Katherine A. Smith. 2006. "Quantitative Implications of a Debt-Deflation Theory of Sudden Stops and Asset Prices." *Journal of International Economics*.

[27] Mendoza, Enrique G. and Vivian Z. Yue. 2007. "Solving the Country Risk - Business Cycle Disconnect: Endogenous Output Collapse in a Model of Sovereign Default." Unpublished Paper, University of Maryland.

[28] Neumeyer, Pablo A. and Fabrizio Perri. 2005. "Business cycles in emerging economies: the role of interest rates." *Journal of Monetary Economics*, 52:2, pp. 345-80.

[29] Nicholson, J. L. (1960). "The Effects of International Trade on the Measurement of Real National Income." *The Economic Journal*, Vol. 70, No. 279 (Sep., 1960), pp. 608-612.

[30] Petrin, Amil and James Levinsohn. 2005. "Measuring Aggregate Productivity Growth Using Plant Level Data." Unpublished paper, University of Michigan.

[31] Rasmussen, P. N. (1956). *Studies in Inter-Sectoral Relations*. Amsterdam: North-Holland.

[32] Restuccia, Diego and Richard Rogerson. 2003. "Policy Distortions and Aggregate Productivity with Heterogeneous Plants." University of Toronto Working Paper.

[33] Rossi-Hansberg, Esteban and Mark L. J. Wright. 2007. "Establishment Size Dynamics in the Aggregate Economy." *American Economic Review*, 97:5, pp. 1639-66.

[34] Shari, Ishak. 2001. "Financial Crisis and its Social Impact in Malaysia," in The Social Impact of the Asian Financial Crisis. Yun-Peng Chu and Hal Hill eds. Cheltenham: Edward Elgar.

[35] Solow, Robert M. 1957. "Technical Change and the Aggregate Production Function." *The Review of Economics and Statistics*, 39:3, pp. 312-20.

[36] Stuvel, G. (1959) "Asset Revaluation and Terms of Trade Effects in the Framework of the National Accounts". *Economic Journal*, Vol. LXIX, no. 274, June 1959, pp. 275-292.

[37] Suryahadi, Asep, Sudarno Sumarto, Yusuf Suharso, and Lant Pritchett. 2000. "The Evolution of Poverty during the Crisis in Indonesia, 1996-99." World Bank Policy Research Working Paper, 2435.

[38] Weitzman, Martin L. 1976. "On the Welfare Significance of National Product in a Dynamic Economy." *The Quarterly Journal of Economics*, 90:1, pp. 156-62.