

February 14, 2011

The Costs of Financial Crises: Resource Misallocation, Productivity and Welfare in the 2001 Argentine Crisis

Guido Sandleris*

Universidad Torcuato di Tella

Mark L. J. Wright*

University of California, Los Angeles, and
National Bureau of Economic Research

ABSTRACT

Financial crises in emerging market countries appear to be very costly: output falls are often dramatic, while a host of partial welfare indicators deteriorate as well. The magnitude of the decline in output is puzzling from an accounting perspective, as factor usage does not decline as much as output, resulting in large falls in measured productivity. Furthermore, if productivity is associated with technology, we have no theory to explain why technology should deteriorate during a crisis. In this paper, we present a framework that allows us to *account* for observed changes in a country's productivity during a financial crisis, and to *measure* the resulting change in the country's welfare. Specifically, we show how to decompose the change in an economy's measured productivity into changes in the efficiency with which resources are allocated across and within sectors and other factors. This framework allows us to measure the welfare costs of a financial crisis, and to decompose 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 find that more than half of the roughly 11% decline in measured total factor productivity can be accounted for by deteriorations in the allocation of resources both across and within sectors. We measure the decline in welfare to be on the order of 15% of one year GDP.

*We thank seminar participants at the Bank of England, the Bank of Spain, Universidad de San Andres, CREI, HEC, IIER, the Paris School of Economics, UCLA, UCSB, the 2009 LACEA Conference, and the 2008 and 2009 SED Conferences 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 are costly: declines in economic activity are large, while a host of social indicators suggest that welfare falls substantially, too. For example, in the months surrounding the sovereign default and devaluation in Argentina at the end of 2001, output fell by 15 per-cent, down 20% from its previous peak, while unemployment exceeded 20% and poverty rates doubled leaving almost half of the population below the poverty line. Similar effects were also observed in the Asian Crisis economies in 1997 and 1998¹.

The magnitude of the decline in output is hard to explain. From an 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.

What factors account for the decline in observed productivity? What was the impact of this decline on welfare? And how much did welfare decline during the crisis? In this paper, we present a framework that allows us to *account* for observed changes in a country's productivity during a financial crises, and to *measure* the resulting change in the country's welfare. Specifically, we show how to decompose the change in an economy's measured productivity into changes in the efficiency with which resources are allocated across sectors, changes in the efficiency of the resource allocation within sectors driven both by reallocation amongst existing plants, as well as reallocation driven by both entry and exit, and changes in the underlying technology of the economy. We then show how to combine this measure with data on government spending, movements in the terms of trade, and in a country's international investment position, to measure the aggregate change in welfare of the economy.

We apply this framework to the 2001 Argentine financial crisis using a unique dataset on the behavior of manufacturing establishments throughout the crisis, combined with na-

¹Similar effects were observed in the the Asian crisis economies in 1997 and 1998: poverty rates more than doubled in Indonesia (Suryahadi et al [38]); domestic violence increased 20% in Malaysia (Shari [35]); child mortality rates increased 30% in Indonesia (Blutta et al [8]); murders increased by 27.5% in Thailand (Knowles et al [23]); suicide rates increased 20% in Korea (Lee [24]).

tional accounting data. We find that the productivity of the manufacturing sector of the Argentine economy fell by 11.5 per-cent between 1997, the year before the crisis became anticipated, and 2002. Of this decline, we find that we can account for more than half, and in some cases as much as two thirds, as the result of a deterioration in the efficiency with which resources are allocated both across and within industries. Of this, the largest contributions come from deteriorations in the allocation of resources, and particularly labor, within industries.

We then turn to measuring the change in welfare induced by the crisis and find that the decline in welfare is by an amount equivalent to a one-quarter reduction in GDP in the year 1998. This is driven predominantly by reductions in measured productivity (from both increased misallocation and other sources) with some significant, although mostly offsetting contributions from the change in the countries net foreign asset position, the prices at which it trades with the rest of the world, and through tighter constraints on the governments ability to waste resources.

Our paper builds on several literatures. Like Chari, Kehoe and McGrattan [9], Meza and Quintin [25], Benjamin and Meza [7], Kehoe and Ruhl [21], Christiano, Gust and Roldos [11], Neumeyer and Perri [29], Mendoza [26], Mendoza and Yue [28], Arellano and Mendoza [1] and Mendoza and Smith [27], 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 [39], 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 [22]; 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 [36], Hulten [19], Baily et al [4], Basu and Fernald [5], Petrin and Levinsohn

[31], and the work surveyed in Foster et al [13], we study the relationship between technological progress at a plant level, reallocation of factors across plants, 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, and to studies of the role of “wedges” at an aggregate level as in Cole and Ohanian 2005 and Chari, Kehoe and McGrattan [10]. Finally, in contrast to Restuccia and Rogerson [33] and Hsieh and Klenow [18] who study deviations from the *optimal* allocation of resources across plants within different countries at a point in time, our paper studies the relative contribution of across industry reallocation, within industry reallocation among existing plants, and within industry reallocation induced by entry and exit, in producing changes in the *actual* allocation of resources for one country over time.

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. Rather than encoding a theory of a financial crisis, the model is intended as a measurement and accounting device: a number of exogenous variables, or “wedges”, are introduced that are just identified by the data. The model then provides a framework for aggregating these wedges to account for observed changes in productivity and for measuring the (otherwise unobserved) change in welfare.

Consider a world that is deterministic; all agents in the economy have perfect foresight,

except with regard to the advent of the international financial crisis which is modeled as a completely unanticipated event. The economy is small open, taking world interest rates and the prices of its imports and exports as given; trade need not be balanced, so that the net foreign asset position of the country is evolving over time. There is a government that collects tax revenue and expends resources that may be valuable to households. There are many industries producing different goods, with these goods aggregated to form the national accounts expenditure categories. Production takes place in plants that act competitively, each facing plant specific distortions – the “wedges” – that affect their incentive to produce at all, as well as to hire the various factors of production. These wedges stand in for a wide range of factors, that might be part of the technology of the economy, or the market environment, that drive a wedge between the price plants pay for a factor and the price received by the supplier of the factor; they 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

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

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. The household first decides how many investment goods to purchase, I_t , which cost 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 a crisis that occurs 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

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

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

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

with initial capital and bonds given at time $t = 0$. Here Π_s represents any profits earned by plants 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 $W_t(\hat{K}_t, B_t)$ 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

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

subject to

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

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

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

while the envelope conditions are

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

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 plants (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 of Basic Commodities

We consider an economy with J basic commodities produced in separate competitive 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 its 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 plants 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 plant. We 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 that occur during the financial crisis as the impact of the financial crisis on the resource allocation mechanism.

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

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

so that the first order conditions for an optimum are

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

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 plants expectations about future production decisions. In particular, we assume that plants must pay the fixed cost $P_K F$ to produce in each period. After paying the fixed cost, plants

then learn about their type i which is drawn from 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 plants decision to produce *ex post*. Entry occurs as long as expected profits are positive, and so in equilibrium we must have

$$\sum_i \pi_i \left[(1 - \gamma) P_Y Y_i - \frac{P_K}{(1 - \tau_{Fi})(1 - \tau_{Ki})} F \right] = 0. \quad (4)$$

We let N denote the total number of plants that produce in a period. Our assumptions allow us to work with the data as though there were repeated cross sections of plants.

In this framework, if all plants 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 plants 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

$$Y = N \sum_i \pi_i Y_i, \quad (5)$$

relative production is given by

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

where we have defined $1 - \tau_i$ to be the *scale wedge* of the plant 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 plant 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 plants first order conditions we can obtain expressions for industry factor shares as fractions of the production parameters and output weighted average wedges

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

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

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

where μ is the ratio of revenues not paid to labor and intermediate inputs, to the payments made to capital; if all wedges are zero, $\mu = 1$.

2.D Industries, Sectors and Aggregation

There are four final goods in the economy: an aggregate consumption good C , an investment good I , a government spending good G , and an export good X . In addition there is an aggregate intermediate input. Each of the final commodities plus the aggregate intermediate input are produced using some combination of the J basic commodities along with the imported good M using a constant returns to scale technology that is operated by competitive plants. The technology for producing the final consumption good, for example, is represented by

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

where C_{jt} represents the amount of output from industry j , and M_{Ct} the amount of the import good, used for final consumption, and H^C is a homogenous of degree one function. Analogous homogeneous of degree one aggregators H^k exist for $k = I, G, X$, and Q . The constraints on the usage of each commodity j are given by

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

with use of the import good constrained by

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

The assumption of constant returns to scale combined with the assumption that these technologies are operated by competitive plants ensures that the price of each of these aggregates P_{kt} for $k = C, I, G, Q$ is a homogeneous of degree one function of the prices of the import good and each of the J basic commodities; as we are modeling a small open economy, we take the prices of both exports P_{Xt} and imports P_{Mt} as 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 think-

ing 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 τ '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).

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 Measuring Misallocation During The Argentine Crisis of 2001

The model introduced above is intended as a device to (1) measure the changing efficiency of the resource allocation during a financial crisis; (2) account for the observed decline in measured productivity; and (3) measure the resulting change in welfare. In the next three sections we implement each of these steps in turn using data from Argentina around the crisis of 2001.

The Argentine crisis 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. The crisis ended 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. During the crisis, 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 and the first quarter of 2002 when the quarterly changes in output were -5.7 and -5.0 per-cent respectively.

3.A The Microeconomic Data

We obtained data on the performance of Argentine manufacturing establishments from the annual industrial survey (*Encuesta Industrial Anual*) carried out by the Argentine Institute of Statistics and Census (INDEC). This survey is conducted in March of each year; that is, the data for 2001 were collected in March of 2002. Participation by establishments is determined randomly within each of the 5 digit subsectors in the Central Product Classification

of the United Nations. Each establishment is followed over time for as long as it continues operation. Disappearing establishments are not replaced until a new Industrial Census is carried out, which happens roughly every ten years.² New entrants to the survey that have been in existence for more than one year are distinguished 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.³

The survey provides information on a range of plant characteristics including the year in which activities began, whether it is the only plant of a firm, foreign ownership (share of foreign capital equal to 0%, between 0% and 10%, more than 10%), and an industry identifier. 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.

In order to preserve the anonymity of the respondents, INDEC transformed all variables into per worker terms and did not provide us the exact number of workers in each plant. 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. However, INDEC did provide us with data on the growth rate of the number of workers. This allows us to capture the evolution of each of the variables of interest.

As can be seen analyzing the FOCs, the absence of exact data on the level of employment has no effect on the calculation of the wedges (the $\tau's$) reported below; it only affects the process by which we aggregate these results to form conclusions about aggregate productivity in the next section. For this, we need an estimate of the number of employees in each plant.

²Ocasionalmente, new establishments may be included in the survey in between census following special studies of a given sector.

³Employment in the manufacturing sector accounts for approximately 20% of total employment.

We experimented with several methods for imputing establishment size. For our benchmark method, 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 plants (45 workers for small plants, 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 plant, we adjust the initial number of workers to place the establishment at the boundary of that size category. For large plants that do not change size categories we set their number of workers so that we obtain the aggregate level of employment of plants in the sample from the aggregated data. Except where noted in the text, and as discussed in the appendix, our results are robust to a number of alternative methods for imputing establishment size. Moreover, as shown in the appendix, our method yields aggregate data that closely match the performance of the manufacturing sector.

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, a relatively normal year for the country, to compute $\alpha_j\gamma$ and $\beta_j\gamma$ (and hence also $(1 - \alpha_j - \beta_j)\gamma$) for each year under the assumption that wedges are zero in 1997. 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).

For the purposes of our analysis, 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

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

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 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 plant specific prices nor output. To recover output from the value of 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.

3.B Capital and Capital Services

Capital utilization is likely to have varied throughout the crisis. In addition, our establishment level dataset does not include the balance sheet of the plant, and so we do not have estimates of the book-value of the plants capital stock. Hence, we assume that capital devoted to production is used to produce *capital services* KS using a Leontieff production function of the form

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

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

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

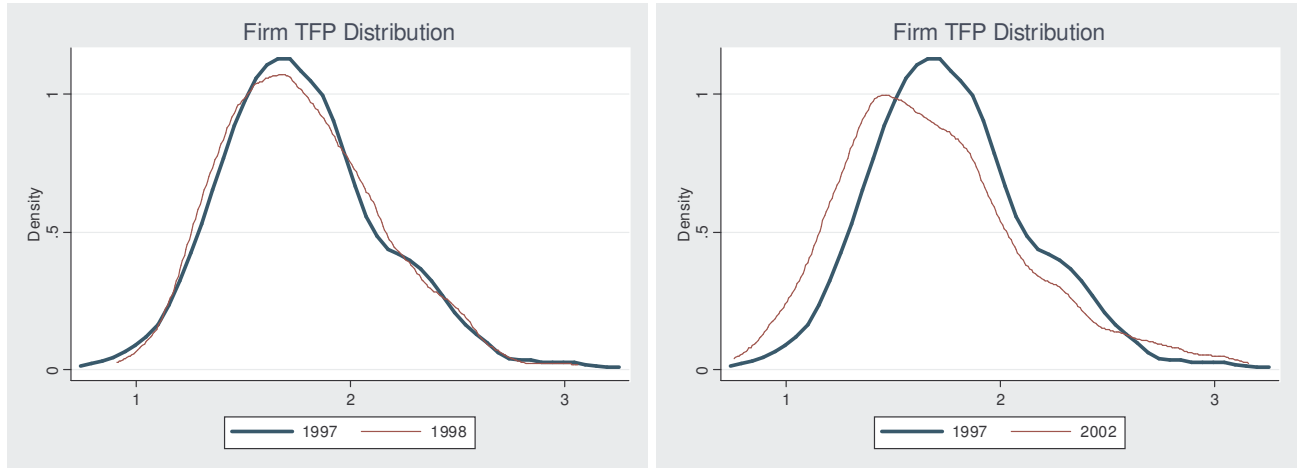
Hence, we can identify the capital wedge up to a constant from

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

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

3.C Results

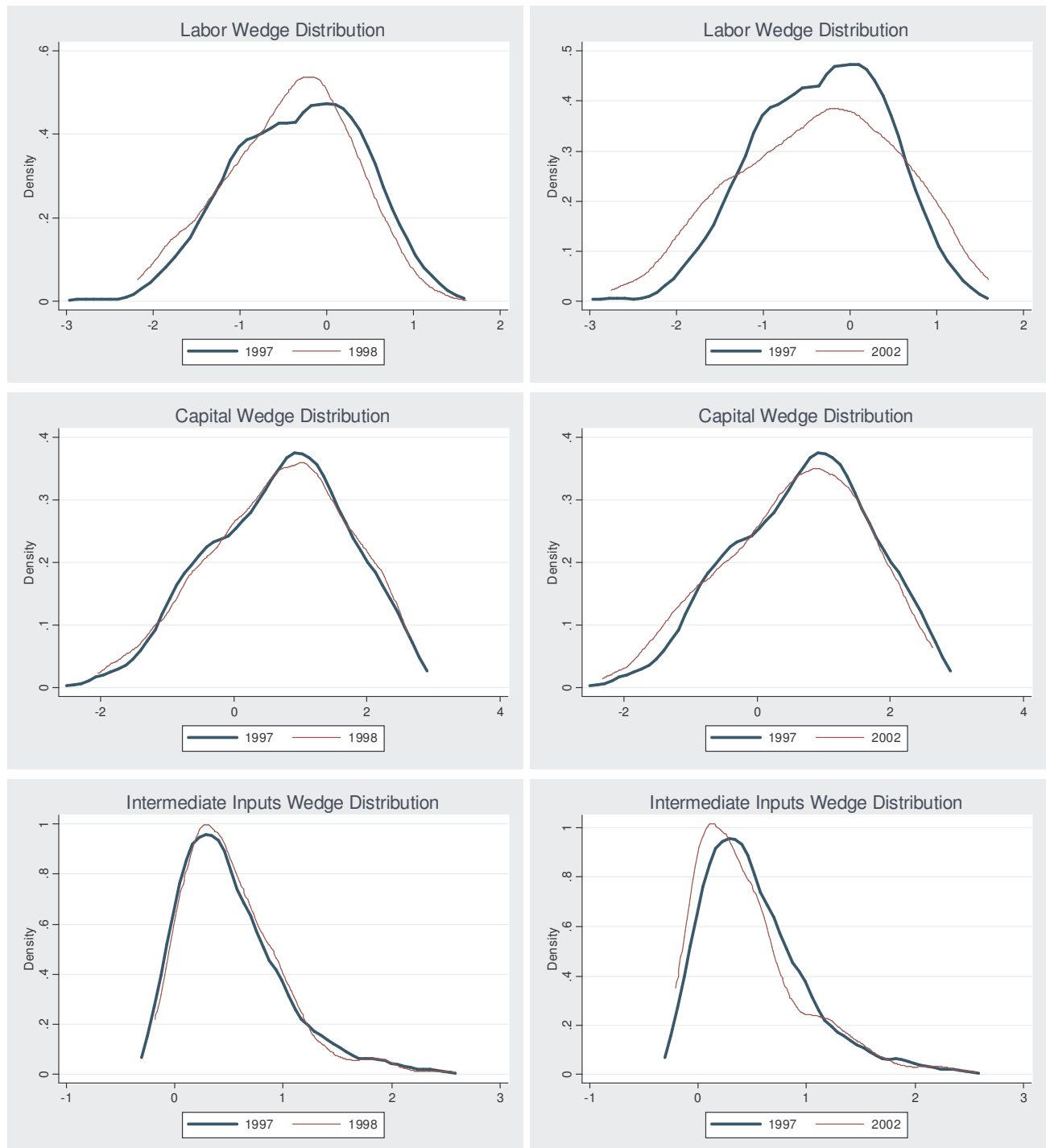
First, we look at the distribution of wedges and productivity for 1997 and for 2002. The following figures show the distribution of establishment productivity for surviving plants in the sample, relative to industry average, after excluding the top and bottom 1% of observations. We observe that between the relatively normal years of 1997 and 1998, there was little change in this distribution.⁴ However, when comparing 2002 to 1997, we see that there was a marked fattening of both tails of the distribution.



The next three sets of figures present the analogous pictures for the different factor wedges. In the first set, we see that there was a fattening of the left tail in the labor wedge distribution between 1997 and 1998. Negative wedges suggest establishments are retaining more workers than desired, which possibly reflects an increase in labor hoarding between these years. However, at the same time there was an increase in the density in the middle of the distribution. Between 1998 and 2002, there was a substantial fattening of both of the tails

⁴A similar thing happens if we were to compare against 1999 or 2000.

of the distribution. This is consistent with a large decline in the efficiency with which labor is allocated, with those establishments with negative wedges wishing to reduce employment, and those with positive wedges wanting to increase their employment. In comparison, the movements in the capital and intermediate input wedge distributions are more modest.



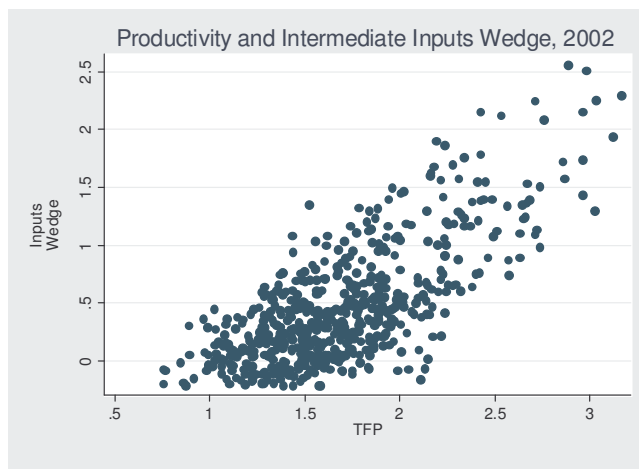
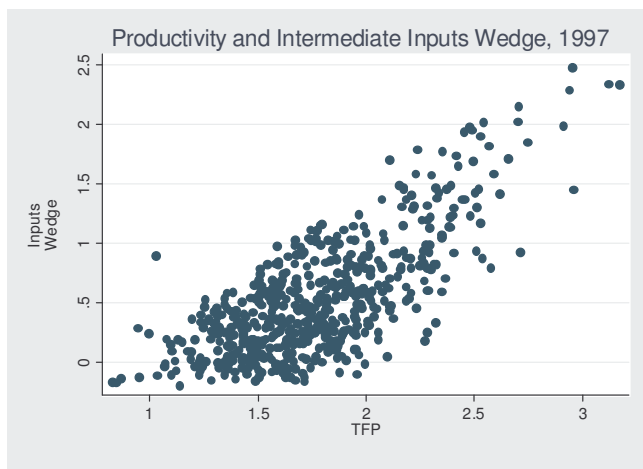
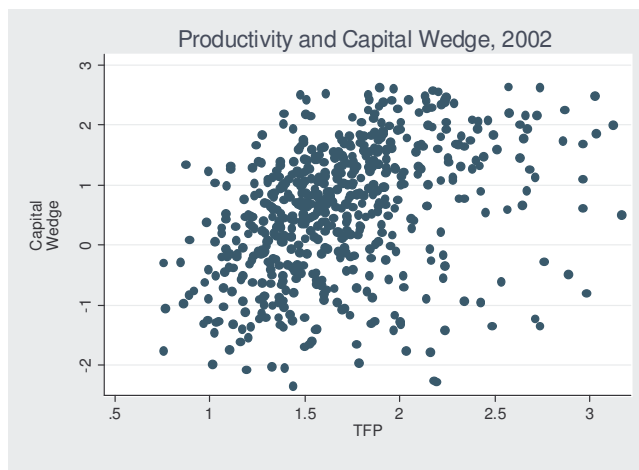
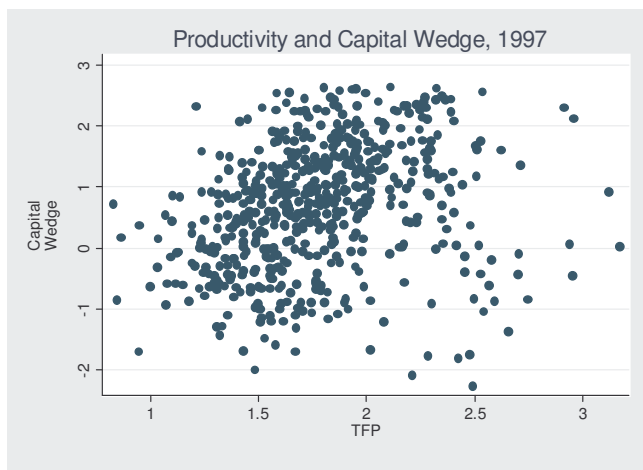
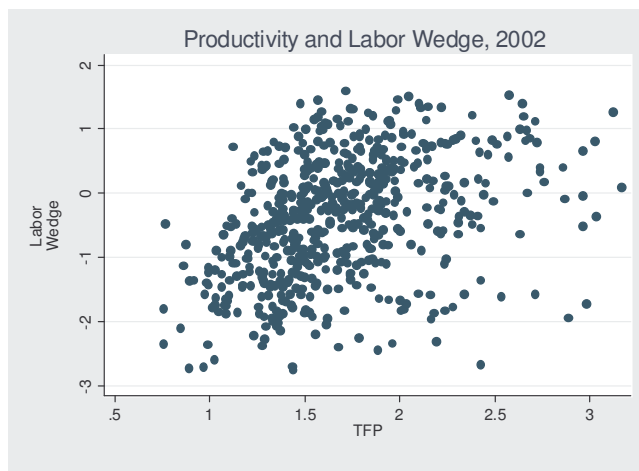
The following table shows some descriptive statistics for the joint distribution of wedges and productivity in Argentina. The table shows that mean total factor productivity falls slightly, while the mean labor wedge rises, suggesting that on average establishments face more difficulty increasing their employment of labor. Both the wedges for capital and intermediate inputs fall slightly on average.

Dispersion in productivity as well as both the labor and capital wedges also increase, with the largest changes observed for the labor wedge. Dispersion in the intermediate wedge falls. Both the labor and intermediate input wedges become more correlated with output suggesting that the most efficient establishments become more constrained in their ability to increase employment of these factors, while the correlation with the capital wedge declines.

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				
Mean	6.35	0.93	1.95	3.15
Std Dev	2.76	0.68	1.35	3.02
90-10	6.12	1.58	2.17	7.25
75-25	2.70	0.87	1.01	3.25
Correlation with A_i	1.00	0.12	0.80	0.23
2002				
Mean	6.00	1.03	1.87	2.91
Std Dev	3.21	0.92	1.43	2.88
90-10	6.35	2.12	2.35	6.56
75-25	2.82	1.07	0.88	3.10
Correlation with A_i	1.00	0.31	0.76	0.38

The next figures show scatter plots of the log of the wedges against the log of productivity for the years 1997 and 2002. The figures confirm the patterns described by the

statistics in the previous table about correlations and dispersion.



4 Accounting For Changes in Aggregate Productivity

In this section, we examine the extent to which changes in the allocation of resources account for the changes in aggregate output and productivity.

4.A From Plant to Industry Output

Gross output of an industry is simply the sum of the gross output of each plant in the industry (5). Using the form of the production function and our formulae for the allocation of factors across plants (7) we obtain an expression for industry output as a function of industry factor usage

$$Y_j = \Phi_j A_j \left[K_{Pj}^{\alpha_j} L_j^{\beta_j} Q_j^{1-\alpha_j-\beta_j} \right]^\gamma N_j^{*1-\gamma}, \quad (10)$$

where K_P denotes the total amount of capital employed in production, not including the fixed cost paid by each plant, and

$$\begin{aligned} \Phi_j = & \sum_i \pi_i \left\{ (1 - \tau_{Ai}) \left(\frac{(1 - \tau_{Ki})(1 - \tau_i)}{\sum_i \pi_i (1 - \tau_{Ki})(1 - \tau_i)} \right)^{\alpha_j \gamma} \left(\frac{(1 - \tau_{Li})(1 - \tau_i)}{\sum_i \pi_i (1 - \tau_{Li})(1 - \tau_i)} \right)^{\beta_j \gamma} \times \right. \\ & \left. \left(\frac{(1 - \tau_{Qi})(1 - \tau_i)}{\sum_i \pi_i (1 - \tau_{Qi})(1 - \tau_i)} \right)^{(1-\alpha_j-\beta_j)\gamma} \right\}, \end{aligned} \quad (11)$$

captures the effect of the wedges on the allocation of resources and its impact on industry output. Equation 10 establishes that industry output is a constant returns to scale function of the inputs devoted to production, K_{Pj} , L_j , and Q_j , and the number of firms N_j ; that is, it is as though the number of firms is an extra factor of production.

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 $N_j^* = \Lambda_j Y_j$ where

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

This expression is quite intuitive: if fixed costs $P_K F / P_{Yj}$ 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 into (10) and

rearranging yields

$$Y_j = \left(A_j \Phi_j \Lambda_j^{(1-\gamma)} \right)^{1/\gamma} K_{Pj}^{\alpha_j} L_j^{\beta_j} Q_j^{1-\alpha_j-\beta_j}. \quad (12)$$

Equations (10) and (12) constitute a statement of Viner's classic result: even though there are decreasing returns at the plant level, with free entry the industry acts as though it has constant returns to scale by varying the number of plants in operation, each of which produces at the minimum of its average cost curve.

4.B Industry Productivity and Intra-Industry Misallocation

Equation (12) also shows that, if we know the output elasticities α_j and β_j , and calculate industry productivity $\hat{A}_j$ by dividing gross output by the output-elasticity-geometric-weighted-average of factor inputs, we obtain

$$\hat{A}_j = \left(A_j \Phi_j \Lambda_j^{(1-\gamma)} \right)^{1/\gamma}.$$

That is, measured industry productivity depends on: the fundamental level of total factor productivity in the industry, A_j ; a term Φ_j that captures the allocation of resources across plants with different productivities τ_{Ai} , and its misallocation caused by the different costs of hiring factors τ_{Ki} , τ_{Li} , and τ_{Qi} ; and a term Λ_j which captures the efficiency with which the number of plants in the industry varies.

To illustrate the role of allocative inefficiency in determining industry TFP, differentiate 11 with respect to time to show that changes in Φ_j are the result of two effects: First, the effect of reallocation between existing plant types, which we denote by

$$\begin{aligned} R_{1j} = & \sum_i \frac{\pi_i^* Y_i}{\bar{Y}_j} \frac{d(1-\tau_{Ai})}{(1-\tau_{Ai})} + \alpha_j \gamma \sum_i \pi_i \left(\frac{Y_i}{\bar{Y}_j} - \frac{K_i}{\bar{K}_j} \right) \left(\frac{d(1-\tau_i)}{(1-\tau_i)} + \frac{d(1-\tau_{Ki})}{(1-\tau_{Ki})} \right) \\ & + \beta_j \gamma \sum_i \pi_i \left(\frac{Y_i}{\bar{Y}_j} - \frac{L_i}{\bar{L}_j} \right) \left(\frac{d(1-\tau_i)}{(1-\tau_i)} + \frac{d(1-\tau_{Li})}{(1-\tau_{Li})} \right) \\ & + (1-\alpha_j-\beta_j) \gamma \sum_i \pi_i \left(\frac{Y_i}{\bar{Y}_j} - \frac{Q_i}{\bar{Q}_j} \right) \left(\frac{d(1-\tau_i)}{(1-\tau_i)} + \frac{d(1-\tau_{Qi})}{(1-\tau_{Qi})} \right); \end{aligned}$$

Second, the effect of changes in the composition of plant types, which we denote by

$$R_{2j} = \sum_i \pi_i \left(\frac{Y_i}{\bar{Y}_j} - \alpha_j \gamma \frac{K_i}{\bar{K}_j} - \beta_j \gamma \frac{L_i}{\bar{L}_j} - (1 - \alpha_j - \beta_j) \gamma \frac{Q_i}{\bar{Q}_j} \right) \frac{d\pi_i^*}{\pi_i^*}.$$

To understand R_{1j} , 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

$$R_{1j} = \sum_i \pi_i \frac{Y_i}{\bar{Y}_j} \frac{d(1 - \tau_{Ai})}{(1 - \tau_{Ai})}.$$

If all plants start with the same technology level ($\tau_{Ai} = 0$ for all i) so that all firms are of the same size ($Y_i = \bar{Y}_j$), and there is a mean preserving spread in the distribution of τ_{Ai} 's, there is no effect on industry TFP; this is a consequence of the envelope theorem. If, however, 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 productivity increases (in which case the most efficient plants, $Y_i > \bar{Y}_j$, become more productive $d(1 - \tau_{Ai}) > 0$ so that $R_{1j} > 0$) in which case productivity rises, or the variance decreases (the least efficient plants, $Y_i < \bar{Y}_j$, become more productive $d(1 - \tau_{Ai}) > 0$ so that $R_{1j} < 0$) 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

$$\frac{d(1 - \tau_{Ki})}{(1 - \tau_{Ki})} = \frac{-(1 - \alpha_j - \beta_j)}{\alpha_j} \frac{d(1 - \tau_{Qi})}{(1 - \tau_{Qi})}.$$

so that

$$R_{1j} = (1 - \alpha_j - \beta_j) \gamma \sum_i \pi_i \left(\frac{K_i}{\bar{K}_j} - \frac{Q_i}{\bar{Q}_j} \right) \frac{d(1 - \tau_{Qi})}{(1 - \tau_{Qi})}.$$

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 $K_i/\bar{K}_j - Q_i/\bar{Q}_j < 0$ 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 decrease aggregate productivity*.

To understand R_{2j} , note that by definition, $\sum_i d\pi_i^* = 0$, and so, if all plant were identical, $R_{2j} = 0$. When there is heterogeneity, however, everything else equal, an increase in the share of types producing above average amount of output increases productivity ($R_{2j} > 0$) 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 ($R_{2j} < 0$) as this represents an increase in the most distorted plants.

Next, to understand the role of changes in the efficiency of plant turnover in producing industry productivity, note that

$$\frac{d\Lambda_j}{\Lambda_j} = \frac{dP_{Yj}}{P_{Yj}} - \frac{dP_K}{P_K} + \sum_i \left(\frac{d\pi_i}{\pi_i} - \frac{d(1 - \tau_{Fi})}{(1 - \tau_{Fi})} - \frac{d(1 - \tau_{Ki})}{(1 - \tau_{Ki})} \right) \frac{\pi_i}{(1 - \tau_{Fi})(1 - \tau_{Ki})}.$$

These terms reflect the consequences of decreasing returns at a plant level for 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.

In what follows, we will use variation in the consumption of power to capture changes in the amount of capital services utilized by the plant. In some practical applications this might not be possible, and it would be necessary for the researcher to 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

$$K = \left(1 + \Lambda \frac{P_K F}{P_Y} \frac{1}{\alpha \gamma} \frac{\sum_i \pi_i (1 - \tau_i)}{\sum_i \pi_i (1 - \tau_i) (1 - \tau_{Ki})} \right) K_P \equiv (1 + \Lambda \Gamma) K_P \equiv \kappa K_P, \quad (13)$$

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 output produced ($d\Gamma/\Gamma > 0$).

When data on power consumption is available, the analysis is modified in two ways. First, purchases of energy must now be subtracted from gross output to compute value added. 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.

4.C Aggregate Productivity and Inter-Industry Misallocation

Finally, we collect our measures of productivity at the plant and industry levels with measures of aggregate productivity. As we will see below when we discuss welfare, and has been stressed by other authors, the appropriate measure of productivity growth for welfare purposes takes the growth rate of value added and subtracts the growth rates of capital and labor weighted by factor shares computed using the social cost of supplying those factors. In the framework introduced above, households receive the undistorted capital and labor prices, and hence we should weight factor input growth by their simple factor shares. We refer to this as the total factor productivity of the economy, denoted TFP_1 .

In practice, the capital share of income is difficult 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

$$\frac{dTFFP_2}{TFP_2} = \frac{dV}{V} - (1 - \omega_L^V) \frac{dK}{K} - \omega_L^V \frac{dL}{L}, \quad (14)$$

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

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

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

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

where

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

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

$$\frac{dTFFP_2}{TFP_2} = \sum_j \omega_j^V \left(\frac{dV_j}{V_j} - (1 - \omega_{Lj}^V) \frac{\bar{\mu}}{\mu_j} \frac{dK_j}{K_j} - \omega_{Lj}^V \frac{dL_j}{L_j} \right),$$

which is the value added weighted average of the growth in industry Solow residuals adjusted for the capital share measurement issues discussed above⁵.

Finally, to connect with industry and plant 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

$$\frac{dY_j}{Y_j} = \frac{P_{Vj} V_j}{P_{Yj} Y_j} \frac{dV_j}{V_j} + \frac{P_{Qj} Q_j}{P_{Yj} Y_j} \frac{dQ_j}{Q_j} = \omega_{Vj}^Y \frac{dV_j}{V_j} + \omega_{Qj}^Y \frac{dQ_j}{Q_j}. \quad (15)$$

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

$$\frac{dTFFP_2}{TFP_2} = \frac{1}{\omega_V^Y} \sum_j \omega_j^Y \left\{ \frac{dY_j}{Y_j} - (1 - \omega_{Lj}^V) \omega_{Vj}^Y \frac{\bar{\mu}}{\mu_j} \frac{dK_j}{K_j} - \omega_{Lj}^Y \frac{dL_j}{L_j} - \omega_{Qj}^Y \frac{dQ_j}{Q_j} \right\}. \quad (16)$$

Substituting for the change in output in (16) by taking the derivative of equation (12), substituting for industry factor shares from (8) and (9), replacing the change in capital used in production by the change in total capital from (13), and rearranging, we obtain that the growth in the Solow residual $dTFP_2/TFP_2$ is given by

$$\begin{aligned} & \frac{1}{\omega_V^Y} \sum_j \omega_j^Y \left\{ \frac{1}{\gamma_j} \frac{dA_j}{A_j} + \frac{1}{\gamma_j} \left(\frac{d\Phi_j}{\Phi_j} + (1 - \gamma_j) \frac{d\Lambda_j}{\Lambda_j} \right) - \alpha_j \frac{d\kappa_j}{\kappa_j} \right. \\ & + \alpha_j (1 - \gamma_j (1 - \bar{\tau}_K) \bar{\mu}) \frac{dK_j}{K_j} + \beta_j (1 - \gamma_j (1 - \bar{\tau}_L)) \frac{dL_j}{L_j} + (1 - \alpha_j - \beta_j) (1 - \gamma_j (1 - \bar{\tau}_Q)) \frac{dQ_j}{Q_j} \\ & \left. + \alpha_j \gamma_j (\bar{\tau}_{Kj} - \bar{\tau}_K) \frac{dK_j}{K_j} + \beta_j \gamma_j (\bar{\tau}_{Lj} - \bar{\tau}_L) \frac{dL_j}{L_j} + (1 - \alpha_j - \beta_j) \gamma_j (\bar{\tau}_{Qj} - \bar{\tau}_Q) \frac{dQ_j}{Q_j} \right\}, \end{aligned} \quad (17)$$

⁵If $P_K K_j = P_V V_j - P_L L_j$, then this expression reduces to the value added weighted growth rate of industry Solow residuals

$$\frac{dTFFP_1}{TFP_1} = \sum_j \omega_j^V \left(\frac{dV_j}{V_j} - (1 - \omega_{Lj}^V) \frac{dK_j}{K_j} - \omega_{Lj}^V \frac{dL_j}{L_j} \right),$$

where $\bar{\tau}_K, \bar{\tau}_L$ and $\bar{\tau}_Q$ 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 effect of the changing misallocation of factors across sectors. This term will be zero if either there is no inter-industry reallocation occurring (so that $dK_j/K_j = dL_j/L_j = dQ_j/Q_j = 0$ for all j), or if marginal products are equated across industries (so that $\bar{\tau}_{Kj} = \bar{\tau}_K$, $\bar{\tau}_{Lj} = \bar{\tau}_L$, and $\bar{\tau}_{Qj} = \bar{\tau}_Q$ for all j). Otherwise, the changing allocation of resources across sectors will affect measured aggregate productivity. 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 industry j than on average (or $\bar{\tau}_{Lj} > \bar{\tau}_L$) a reallocation of labor to this industry, and away from lower marginal product industries, will increase the Solow residual.

4.D Results

Ideally, to apply the above methodology to Argentine data, we should possess plant level data for the entire economy which could then be compared with national accounts data. However, our plant level data covers only the manufacturing sector, and Argentine national accounts data are subject to potentially serious measurement error.

To understand the source of this error, note that in the theory above, movements in real GDP were constructed from the production side of the national accounts using equation (15) 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

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

In the case of Argentina, the primary measure of 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 available⁶ To see the size of the potential measurement error this induces, 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

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

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

where we have exploited the fact that in the base year $P_V V = P_{VM} V^M$. This shows that if intermediate input prices rise at the same rate as output prices, the two measures are equivalent, while if they rise faster⁷ the growth rate of real value added will be understated. As shown in the appendix, the relative price of intermediate inputs to output rose substantially during this period. As a consequence, we focus entirely on estimates for the manufacturing sector derived from our sample data, treating our sample as representative of the entire manufacturing sector, and the manufacturing sector as though it is representative of the entire Argentine economy.

Table : Accounting For The Fall in Argentine Productivity

All Plants					
	Change From 1997 (% Chained)				
	1998	1999	2000	2001	2002
Manufacturing Total Factor Productivity (TFP_2)	-7.45	-6.06	-3.45	-11.45	-5.88
Intra Industry Misallocation	-3.66	-1.67	-0.47	-7.28	-1.96
Inter Industry Misallocation	-0.47	0.57	1.01	-0.17	-1.19
Residual (Technology and Mismeasurement)	-3.32	-4.96	-4.09	-4.00	-2.73

Table 4.D reports the change in Solow residual derived from our data, and decomposes the sources of its changes into four main components. The change in each component from one year to the next was calculated at an industry level, aggregated using the Tornqvist approximation to the Divisia index and then chained to produce an estimate of the change relative to 1997. Results using a chained Fisher Ideal index are presented in the appendix.

As shown in the Table, our measure of the Solow residual drops dramatically in 1998 before recovering somewhat in 1999 and 2000, only to drop dramatically once again in 2001 reaching a trough of 11.45% below its previous peak. The Solow residual then recovers sharply in 2002 mirroring the sharp recovery in the entire economy. The contribution of intra-sector misallocation mirrors this pattern, explaining half of the initial decline in 1998, producing almost all of the decline between 2000 and 2001, and accounting for roughly two-thirds of

⁷This might be expected to be the case during a financial crisis with imported intermediate inputs priced in foreign currency; see Mendoza and Yue [28] for a discussion.

the cumulative decline in the Solow residual to that point. A recovery in intra-industry misallocation in 2002 results in this item accounting for slightly more than one-third of the entire movement in the Solow residual between 1997 and 2002.

The contribution of inter-industry misallocation is more modest with the exception of between 2001 and 2002 where it led to a full percentage point decline in the Solow residual and ends up accounting for one-fifth of the entire change between 1998 and 2002. In total, our methodology finds that changes in the allocation of resources account for almost two-thirds of the decline in the Solow residual from the previous peak in 1997 to the trough of the crisis in 2001, and more than half of the decline up to 2002. Consequently, the residual term, which captures both the underlying changes in total factor productivity plus measurement error terms is never more than 5 per-cent below its level in 1997 and accounts for only one-third of the drop into the trough of 2001 at the height of the crisis.

All of the results above have been computed for the entire sample of plants used to measure the wedges in Section 3. A feature of the data through this period is that there was a large amount of turnover in the plants represented in the survey, with a large number of plants exiting the survey in 2001 and 2002. The methodology of the survey specifies that a plant should remain in the survey as long as it remains in operation, and so we have interpreted this exit from the survey as exit from production. However, it is plausible that non-response rates increased during the crisis, and that ability of INDEC to monitor non-compliance decreased.

Table : Accounting For The Fall in Argentine Productivity

	Continuing Plants				
	Change From 1997 (% Chained)				
	1998	1999	2000	2001	2002
Manufacturing Total Factor Productivity (TFP_2)	-1.00	-1.87	-0.48	-9.53	-11.30
Intra Industry Misallocation	-0.77	-0.10	-2.01	-3.04	-5.83
Inter Industry Misallocation	0.36	-0.14	0.30	-0.45	0.10
Residual (Technology and Mismeasurement)	-0.59	-1.63	1.23	-6.04	-5.57

To examine the effect of this exit with a view to both establishing the robustness of our results, and towards an understanding of the role of plant turnover in affecting the efficiency

of the allocation of resources, Table 4.D replicates the analysis of Table 4.D for the subset of all plants that responded to the survey in every year from 1997 to 2002. In contrast to the results on the entire sample, the declines in the Solow residual computed using data from the sample of continuing plants are more modest in 1998, and yet more severe in 2001. There is also no increase in the Solow residual between 2001 and 2002.

The effect of intra-industry misallocation is still very large, accounting for more than three-quarters of the initial decline in the Solow residual in 1998, slightly less than one-third of the decline in the height of the crisis, are more than half of the overall decline by 2002. This is consistent with the idea that in the initial years of the crisis, a number of relatively efficient plants exited production, only to be replaced by plants that were either more efficient, or more able to increase efficiency, in 2002 as the economy responded to the crisis. Inter-industry misallocation has more modest effects using the sample of continuing plants, suggesting that the bulk of inter-industry reallocation is accounted for by the exit and entry of new plants. Overall, misallocation accounts for roughly one-third of the decline in TFP to 2001, and half of the decline to 2002.

5 Measuring The Change in Aggregate Welfare

The above Sections explore the extent to which changes in the efficiency of the resource allocation across sectors accounts for changes in measured factor productivity. But how much did these changes matter for welfare? As welfare is a forward looking object, it is necessary to be precise as to the time the crisis became anticipated. For this purpose, imagine that the economy described above experiences an international financial crisis at time t , which we interpret 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. To begin, we think of the crisis as lasting only one period and then extend the framework to consider a persistent crisis 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

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

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 $\omega_C^E, \omega_I^E, \omega_G^E, \omega_X^E$, 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

$$\frac{dW}{\lambda P_V V} = \left(\frac{dV}{V} - \omega_K^V \frac{dI}{K} - \omega_L^V \frac{dL}{L} \right) + \omega_G^E \left(\frac{\Gamma'(G)}{\lambda P_G} - 1 \right) \frac{dG}{G} \\ + \left(\omega_X^E \frac{dP_X}{P_X} - \omega_M^E \frac{dP_M}{P_M} \right) + \frac{r_B B}{P_V V} \frac{d(r_B B)}{r_B B}, \quad (18)$$

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 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 from 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 position⁸.

Before applying this framework to the data, it is useful to examine how this framework would be applied to our example economies introduced above.

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

From equation (17) which relates the Solow residual to growth in technology, we can

⁸It is possible to derive an equivalent expression with TFP measured using gross national income (GNI) growth, subtracting factor growth weighted by shares in GNI.

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 (18) 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 (17) 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, (17) 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 (18) 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

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

5.A Multi-Period Crises

In the analysis above, we assumed that the crisis lasted only one period. As shown above, however, the Argentine 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 tomorrow's 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

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

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.

5.B Results

Table 5.B collects our measurements on the components of the change in welfare as a result of the crisis. Each element of the table refers to the flow contribution of each component for that year relative to its level in 1997. As above, we compute these changes using the Tornqvist approximation to the Divisia Index.

Table : The Change in Welfare and its Components against 1997

All Firms					
Year	1998	1999	2000	2001	2002
Solow Residual	−7.45	−6.06	−3.45	−11.45	−5.88
Mismeasured Factor Elasticities	0.25	0.45	0.57	0.58	0.65
Foreign Trade Goods	−0.43	−0.87	−0.04	−0.15	10.04
Factors	−0.43	−0.45	−0.47	−0.55	−2.50
Government: Consumption	−0.42	−0.83	−0.92	−0.63	0.10
Consumption & Investment	−0.46	−0.84	−0.32	0.01	0.90
Benevolent $G + I$	−8.05	−6.94	−3.40	−11.57	2.31
Flow Welfare Wasteful G	−8.47	−7.77	−4.32	−12.20	2.41
Wasteful $G + I$	−8.52	−7.77	−3.72	−11.56	3.21

The declines in the Solow residual are taken from Table 4.D above. To obtain the appropriate measurement for welfare purposes we need to correct the Solow residual for the mismeasurement of the capital share of output. Doing so as described in the appendix results in slightly smaller declines in productivity growth as shown in the second row of the Table.

The third line in the Table captures the contribution of changes in export and import prices on welfare. For most years this is quite modest reflecting the fact that early in the crisis trade in Argentina was close to balanced. The exception is the year 2002, where changes in tradeable goods prices produced a 10 per-cent positive contribution to welfare. The reason is that, as shown in Figure 1, by the time the crisis hit in 2001 Argentina had transitioned from a net importer to a net exporter. Moreover, as a result of the depreciation in the Argentine peso, both export and import prices roughly tripled in one year. As Argentina was a net exporter (and by 2002, a substantial net exporter) the higher prices received for its

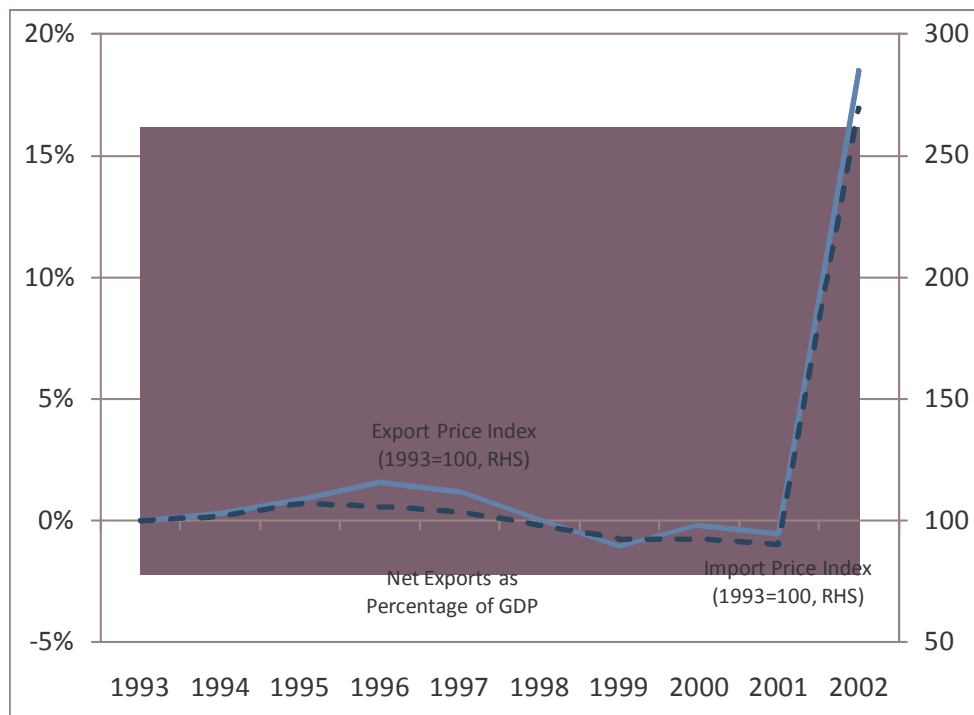


Figure 1: Exports and Imports

exports more than offset the higher prices paid for imports resulting in a substantial increase in welfare.

The fourth line in the Table captures the contribution from changes in income derived from Argentina's foreign investment position. The numbers are negative each year reflecting the fact that Argentina is a net debtor and that the income owed on these debts was increasing each year. The increase is especially large in 2002; despite the write-down in the country's foreign debts, the depreciation of the peso resulted in a large increase in income paid to foreigners which contributed a 2.5 per-cent reduction in welfare that year. It is important to stress that this result using current account data measured on a cashflow basis, which includes the reduction in foreign interest payments as a result of the sovereign default.

If we assume that the government of Argentina is benevolent and sets its expenditure at the point where its marginal social cost equals its marginal social benefit, then we find that the flow effect on welfare is driven predominantly by movements in total factor productivity in every year from 1998 to 2001. Negative contributions from foreign trade in goods and factors

rarely exceed five per-cent of the contribution from productivity. The resulting changes in flow welfare vary from -3.5 to -11.5 per-cent of one years GDP. In 2002, by contrast, the large positive contribution from traded goods prices more than offsets the negative contribution from productivity and all other factors, resulting in an increase in flow welfare of 2.3 per-cent of that years GDP.

To compute the total effect on welfare of the crisis, we need to cumulate the discounted flow changes in welfare. To do so, we use a discount rate of 5 per-cent per year, and assume that the crisis ends in 2003 with all real variables returning to the level they would have been had no crisis occurred. We view the latter as conservative; if the crisis had permanent effects the change in welfare would be much larger. Cumulating welfare flows in this way we find that the crisis reduced Argentine welfare by an amount equivalent to a 24.6 per-cent reduction in 1998 GDP.

If we assume that the government of Argentina is not benevolent, or for some other reason (perhaps due to political economy problems or through the use of distortionary taxation) is unable to equate the social costs and benefits of its spending, we need to take a stand on how far away from the optimum this spending is. As a more or less natural benchmark, we focus on the case in which government spending is purely wasteful. As shown in lines five and six of the Table, depending on whether or not government investment is also considered wasteful, the contribution to welfare from the direct spending of the government is typically on the order of one-half to one per-cent of GDP, negative in periods where government spending rose, and positive when it declined.

Computing the change in welfare as a result of government spending, we find that the welfare numbers are similar to the case with an optimal government. This reflects the fact that the changes in government spending were quite small, and that the government is only a modest component of the overall Argentine economy. Cumulating these discounted welfare flows, we find that the decline in welfare is slightly larger at an amount equivalent to 27 per-cent of 1998 GDP, using only government consumption, falling back to 25.4 per-cent if government investment is included. The reason is that the increases in government spending in the early years of the crisis offset the large fall in government spending in 2002 as the borrowing constraints on the government tightened.

It is, of course, important to be cautious in interpreting these welfare change numbers. Most importantly, our estimates have been designed to be conservative. For one thing, the fact that the sovereign default has still not been fully resolved as of this writing, and access to international capital markets remains limited, suggest that the declines in welfare might extend beyond 2002. At the same time, our assumption of a representative agent means that we do not account for the heterogeneous impact of the crisis on different Argentine citizens. Finally, our approach has nothing to say about the effects of involuntary unemployment on welfare.

6 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. Using conservative assumptions, we found that welfare fell by an amount equivalent to roughly a 25 per-cent in GDP as a result of the crisis. The largest amount of this decline is due to declines in the measured productivity of the Argentine economy, although substantial offsetting improvements in tradeable goods prices, and potentially also tighter constraints on government spending, were also significant. Using micro data on manufacturing plants, 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 than 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 intermediation 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 Southampton 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] International Monetary Fund. (2004). *Balance of Payments Manual*, 5th Edition. Washington D.C.: International Monetary Fund.
- [21] Kehoe, Timothy J. and Kim J. Ruhl. 2006. “Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate” Unpublished Paper, University of Minnesota.
- [22] 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.

- [23] Knowles, James C., Ernesto M. Pernia, and Mary Racelis. 1999. "Social Consequences of the Financial Crisis in Asia." Asian Development Bank Staff Paper, 60.
- [24] 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.
- [25] Meza, Felipe and Erwan Quintin. 2005. "Financial Crises and Total Factor Productivity." Center for Latin American Economics Working Paper, 0105.
- [26] 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.
- [27] Mendoza, Enrique and Katherine A. Smith. 2006. "Quantitative Implications of a Debt-Deflation Theory of Sudden Stops and Asset Prices." *Journal of International Economics*.
- [28] 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.
- [29] 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.
- [30] 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.
- [31] Petrin, Amil and James Levinsohn. 2005. "Measuring Aggregate Productivity Growth Using Plant Level Data." Unpublished paper, University of Michigan.
- [32] Rasmussen, P. N. (1956). *Studies in Inter-Sectoral Relations*. Amsterdam: North-Holland.
- [33] Restuccia, Diego and Richard Rogerson. 2003. "Policy Distortions and Aggregate Productivity with Heterogeneous Plants." University of Toronto Working Paper.

- [34] Rossi-Hansberg, Esteban and Mark L. J. Wright. 2007. "Establishment Size Dynamics in the Aggregate Economy." *American Economic Review*, 97:5, pp. 1639-66.
- [35] 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.
- [36] Solow, Robert M. 1957. "Technical Change and the Aggregate Production Function." *The Review of Economics and Statistics*, 39:3, pp. 312-20.
- [37] Stuvell, 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.
- [38] 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.
- [39] 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.

7 Data Appendix

The plant level data is collected annually by Argentina Statistical Office, INDEC. They collect data on a representative sample of manufacturing establishments with more than 10 employees. According to the latest available census the distribution of plants's sizes and their share on employment was the following.

Number of plants and employment by size class, 1993								
plant size (#N)	Number of plants				Employment			
	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

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 plant, 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 transformed all variables into per worker terms and did not provide us the exact number of workers in each plant. 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. However, INDEC did provide us with data on the growth rate of the number of workers. This allows us to capture the evolution of each of the variables of interest.

As discussed above, the absence of exact data on the level of employment has no effect on the calculation of the wedges (the τ 's). However, it is relevant for the aggregation of the results. We experimented with several methods for imputing establishment size. For our benchmark method, 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 plants (45 workers for small plants, 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 plant, we adjust the

initial number of workers to place the establishment at the boundary of that size category. For large plants that do not change size categories we set their number of workers so that we obtain the aggregate level of employment of plants in the sample from the aggregated data. This method yields aggregate data that closely match the performance of the manufacturing sector as can be shown in the following graph:

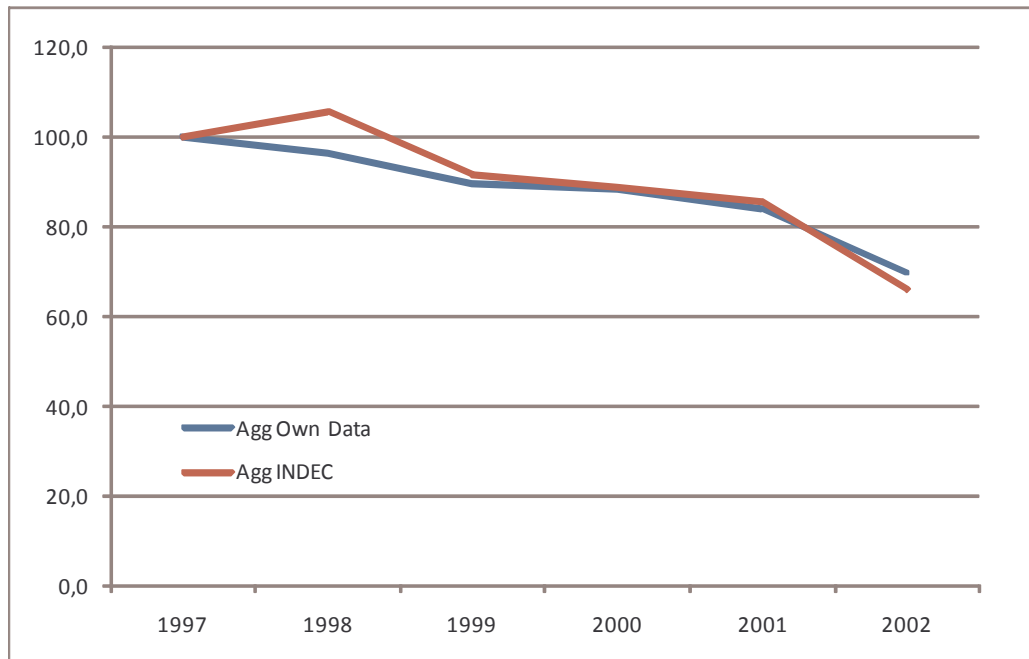


Figure: Gross Value of Production in Manufacturing

8 Balance of Payments Data

As derived above, changes in the flow of net foreign income have a direct effect on the welfare of the representative consumer in this economy: a decrease in the income paid to foreigners increases domestic welfare. We use data from the Argentine balance of payments to estimate these changes. Before doing so, however, we need to confront a number of important measurement issues.

As for most other countries, and as recommended by the International Monetary Fund (2004), the Argentine balance of payments is constructed on an accrual basis. On accrual basis, Argentina's default has no effect on the current account: the payments that were not made as a result of the default are treated as though they were made, and were funded by an offsetting new loan. As a consequence, it is necessary to modify the measure of net factor income from the balance of payments for use in calculating welfare changes. We consider two such adjustments.

The first adjustment we consider is to subtract those payments that were not made as a result of the default. This can be measured from the size of the offsetting loan that appears in the capital account. We refer to this adjusted net factor income series as being measured on a cash basis. However, this measure is also problematic in that it makes no allowance for the expected reduction in future net foreign income paid abroad as a result of the sovereign default.

The second adjustment is designed to capture this effect, and reflects the fact that, by definition, the current account is intended to capture the change in a country's stock of net foreign assets. In practice, a country's stock of net foreign assets can change as the result of transactions, valuation effects reflecting exchange rate movements and capital gains and losses, and as the result of other adjustments such as defaults and nationalizations. The balance of payments, however, was traditionally designed to capture only those changes due to transactions (see IMF 2004 p.6). It is this traditional conception of the balance of payments that is used by Argentina.

However, Argentina does provide estimates of its net international investment position at market prices. Dias, Richmond and Wright (2010) derive conditions under which valuation at market prices is the correct measure of investment positions for welfare purposes, and so

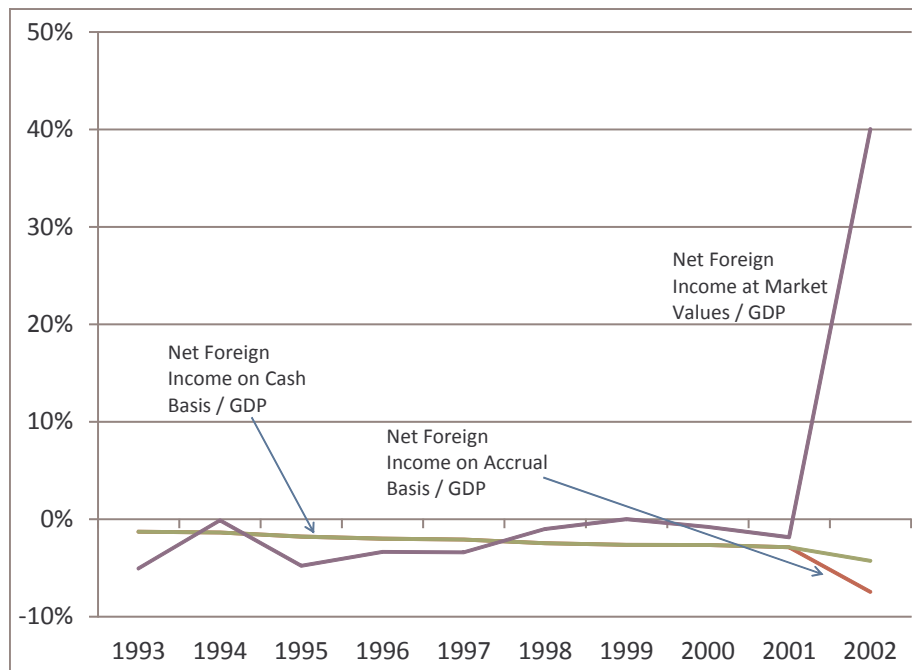


Figure 2:

our second corrected measure of net foreign income is simply defined as the change in the net international investment position at market values minus the trade balance. All three measures are plotted in the next Figure. As shown, when market values are used, the behavior of net foreign income is both qualitatively and quantitatively different. It is these differences that explain the dramatically different results obtained in the text.

9 Welfare with continuing plants only

Table : The Change in Welfare and its Components against 1997

Continuing Plants

Year	1998	1999	2000	2001	2002
Solow Residual	-1.00	-1.87	-0.48	-9.53	-11.30
Mismeasured Factor Elasticities	0.25	0.45	0.57	0.58	0.65
Foreign Trade Goods	-0.43	-0.87	-0.04	-0.15	10.04
Factors	-0.43	-0.45	-0.47	-0.55	-2.50
Government: Consumption	-0.42	-0.83	-0.92	-0.63	0.10
Consumption & Investment	-0.46	-0.84	-0.32	0.01	0.90
Benevolent	-1.60	-2.75	-0.43	-9.65	-3.11
Flow Welfare Wasteful G	-2.02	-3.58	-1.35	-10.29	-3.01
Wasteful $G + I$	-2.07	-3.59	-0.75	-9.64	-2.21