

# Total Factor Productivity and Labor Reallocation: the Case of the Korean 1997 Crisis

## Appendices

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## Appendix A: Data for empirical decomposition of TFP

In this appendix we describe the data used in the empirical decomposition of TFP. We use data at a yearly frequency.<sup>1</sup> We need empirical counterparts of  $y_{it}$ ,  $l_{it}$ ,  $k_{it}$ ,  $\theta_i$ ,  $p_i A_{it}$ ,  $y_t$ ,  $l_t$ ,  $k_t$ ,  $\theta$  and  $A_t$ .

Output per sector  $y_{it}$  is real GDP in per capita terms. The data on GDP by sector is reported at basic prices. We assume the working age population is of age 15 and higher. We divide GDP into nine sectors: 1. Agriculture, forestry and fishing; 2. Mining; 3. Manufacturing; 4. Electricity, gas and water supply; 5. Construction; 6. Wholesale and retail trade, restaurants and hotels; 7. Transport, storage and communication; 8. Financial services and real estate and 9. Public. Public is the sum of public administration, health, education and other activities. We label this sector as “public,” because this sector contains the public sector and other industries traditionally associated with the provision of public goods.<sup>2</sup> We choose the base year to be 1997, the year of the crisis. We adjust GDP and investment data by the relevant deflators so that nominal and real variables have the same value in 1997.<sup>3</sup>

We measure labor by sector  $l_{it}$  by computing the total number of hours worked in each sector in per capita terms. We use data on average hours worked in each sector and multiply them by employment data by sector.<sup>4</sup> We measure hours worked relative to total discretionary time available in a year, which we assume is 5200 hours. We construct hours worked up to 2000 because the reporting of data on employment beyond the year 2000 uses a smaller number of categories.<sup>5</sup> Consequently, we cannot measure TFP by sector past 2000.

Sector specific effective capital,  $k_{it}$ , is constructed using investment data. In this paper, we measure capital utilization by sector. The aim is to eliminate a source of changes in measured TFP that is well understood.<sup>6</sup> We implement the measurement of variable capital utilization in

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<sup>1</sup>Our data sources are the National Statistical Office of Korea, [www.nso.go.kr](http://www.nso.go.kr) and the Bank of Korea, [www.bok.or.kr](http://www.bok.or.kr).

<sup>2</sup>In 1997, public administration represents 34.2% of GDP in this sector. The share for education was 31.0%. The share for health was 15.8%. In terms of employment, data for 2005 shows that, within education, 67% of teachers work in public schools as well as 51.8% of administrative staff.

<sup>3</sup>Korean data has a given base year of 2000. We use 1997 prices because they are more relevant to the events of the crisis than 2000 prices.

<sup>4</sup>There is no data on average hours worked in agriculture. We assume that average hours in that sector behave as average hours in aggregate data.

<sup>5</sup>After this year, the National Statistical Office of Korea reports data for a reduced number of sectors. These sectors are i) Agriculture, forestry and fishing; ii) Mining and manufacturing; iii) Manufacturing and iv) Services.

<sup>6</sup>Adjusting capital stocks at the sectoral level as opposed to the aggregate level does not significantly affect results.

each sector in a similar manner to Meza and Quintin (2007). They use the model of Greenwood, Hercowitz, and Huffman (1988) to calculate capital utilization, depreciation rates, and capital stocks. We implement this procedure in Appendix B in a multi-sector model. We measure the capital stocks in each sector in per capita terms.

We measure sector-specific capital income shares  $\theta_i$  using the Korean 1995 input-output matrix. We rearrange the sectors in the matrix into the nine sectors listed above. We adjust labor compensation in each sector taking into account the income of the self-employed.<sup>7</sup>

Using these data, measured TFP in sector  $i$  (in terms of base year prices) is:

$$p_i A_{it} = \frac{y_{it}}{k_{it}^{\theta_i} l_{it}^{1-\theta_i}}.$$

In the data we observe value. We cannot distinguish price from quantity. Therefore the empirical counterpart of  $p_i$  is implicit in measured  $A_{it}$ . We use these sector specific productivities to calculate *approximate* TFP,  $A_t^a$ .

We require aggregate variables to measure  $A_t$ . The empirical counterpart of  $y_t$  is the sum of sectoral outputs  $y_{it}$ . The counterpart of  $l_t$  is the sum of sectoral labor inputs  $l_{it}$ . To construct the counterpart of  $k_t$  we calculate the sum of effective capital in each sector. We measure the aggregate capital income share  $\theta$  from the input-output matrix, finding a value of 0.25.<sup>8</sup>

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<sup>7</sup>This adjustment is explained in more detail in the calibration section of the paper. The capital shares for the nine sectors in the next section are: (1.) Agr., 0.35 (2.) Min., 0.32 (3.) Manuf., 0.29 (4.) Elec., 0.51 (5.) Const., 0.15 (6.) Trade., 0.25 (7.) Trans. 0.30., (8) FIRE, 0.30 and (9) Public., 0.09.

<sup>8</sup>Detrended aggregate TFP fell by 2.6% between 1997 and 1998. We use the Hodrick Prescott trend.

## Appendix B: Measuring capital utilization, depreciation rates and capital stocks

In this appendix we present a method for measuring capital utilization, depreciation rates and capital stocks for the nine-sector model mentioned in the empirical section of the paper.

Consider a given sector  $j$ . Firms in this sector can alter the rate at which they utilize capital. Raising utilization in a given period raises output, but it also raises the quantity of capital lost to depreciation.

Specifically, depreciation  $\delta_{jt}$  depends on utilization  $u_{jt}$  as follows:

$$\delta_{jt} = \frac{u_{jt}^{\lambda_j}}{\lambda_j},$$

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

$$A_{jt} (u_{jt} k_{jt})^{\theta_j} l_{jt}^{1-\theta_j},$$

where  $A_{jt}$  is TFP,  $k_{jt}$  is capital,  $l_{jt}$  is labor and  $\theta_j$  is the capital income share.

Firms choose  $k_{jt}$ ,  $l_{jt}$ , and  $u_{jt}$  each period to maximize:

$$p_{jt} A_{jt} (u_{jt} k_{jt})^{\theta_j} l_{jt}^{1-\theta_j} - w_{jt} l_{jt} - (r_{jt}^k + \delta_{jt}) k_{jt},$$

where  $r_{jt}^k$  is the rental price of capital paid to consumers and  $w_{jt}$  is the wage. Variable  $p_{jt}$  is the relative price of output in this sector. An investment goods sector is the numeraire.

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

$$u_{jt} = \left( \theta_j \frac{p_{jt} y_{jt}}{k_{jt}} \right)^{\frac{1}{\lambda_j}}.$$

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

$$A_{jt} = \frac{y_{jt}}{(u_{jt} k_{jt})^{\theta_j} l_{jt}^{1-\theta_j}}.$$

We measure the capital stock and the utilization rate inductively. Using an initial capital stock and a value for  $\lambda_j$  we calculate utilization as defined above. Next period's capital stock can be calculated using the following law of motion:

$$k_{jt+1} = k_{jt} \left( 1 - \frac{u_{jt}^{\lambda_j}}{\lambda_j} \right) + i_{jt},$$

where  $i_{jt}$  is gross capital formation. Proceeding in this way yields a path of utilization, capital and TFP adjusted for utilization.

Implementing this procedure requires values for  $\lambda_j$ , for every sector. Simple algebra shows that in the two-sector model in Section 3 the steady state depreciation rate is equal to  $\frac{r}{\lambda_j - 1}$  where  $r$  is the steady state international interest rate. We choose values of  $\lambda_j$  that imply certain steady state yearly depreciation rates. We choose depreciation rates from Horvath (2000).

What is left is to describe the price sequences. The aforementioned prices are the prices of output in each sector relative to the price of an investment good. We take these prices to be sectoral deflators divided by the deflator for the data analogue of the investment sector in the two-sector model in Section 3.

We carry out this measurement for each of the 9 sectors. As mentioned in the main text, we calculate income shares from the Korean input-output matrix.

There is one technicality that applies to the measurement in the nine-sector model, but does not apply to the measurement in the two-sector model. Measuring capital utilization for some sectors faces the following difficulty: the capital to output ratios are persistently low. As a consequence, the depreciation rates implied by the model of Greenwood, Hercowitz, and Huffman (1988) are too high to construct capital stocks consistent with variable capital utilization. These sectors are Agriculture, forestry and fishing, Mining, Construction, Wholesale and retail trade, restaurants and hotels. We assume constant depreciation rates for these sectors taken from Horvath (2000). Then we back out utilization rates. We assume that in the year of the crisis utilization fell in these sectors in the same average proportion as those for which the measurement procedure was successful.

## Appendix C: The Relationship between Sectoral Reallocation and Labor Hoarding

In this appendix, we derive a relationship between our model and another model in the literature used to account for a large fall in TFP in the case of the Mexican 1994 crisis.

Meza and Quintin (2007) model labor hoarding in a one-sector model. Labor hoarding allows the effort employees choose to adjust freely, while employment is costly to adjust.

The model can be used to measure TFP net of effort. Effort is unobservable to the economist so it is measured through the model. In their model, TFP net of effort is equal to:

$$TFP_t = \frac{y_t}{(k_t)^\theta (l_t \epsilon_t)^{1-\theta}},$$

where  $\epsilon_t$  represents effort. Variable  $y_t$  represents output,  $u_t$  is utilization,  $k_t$  is aggregate *effective* capital and  $l_t$  is aggregate labor.

Equilibrium effort is equal to:

$$\epsilon_t = \left( \frac{1 - \theta}{g^{\nu-1}} \frac{y_t}{l_t} \right)^{\frac{1}{\nu}},$$

where  $\theta$  is the aggregate capital income share,  $\nu > 1$  determines the wage-elasticity of effort and  $g > 0$  is the average number of hours worked per worker. Both  $\nu$  and  $g$  are parameters in their model.

We now link this formula on effort to our research. Remember from the multi-sector model that:

$$y_t = \sum_i p_i A_{it} k_{it}^{\theta_i} l_{it}^{1-\theta_i}.$$

In this expression,  $k_{it}$  stands for effective capital. We combine the last two equations to get:

$$\epsilon_t = \left( \frac{1 - \theta}{f^{\nu-1}} \frac{\sum_i p_i A_{it} k_{it}^{\theta_i} l_{it}^{1-\theta_i}}{\sum_i l_{it}} \right)^{\frac{1}{\nu}}.$$

We reinstate our assumptions in the measurement section that capital income shares are identical across sectors, and that capital and labor are hired competitively at prices that are the same across sectors. It follows that:

$$\epsilon_t \approx \left( \left( \frac{1 - \theta}{f^{\nu-1}} \right) \left( \left( \frac{k_t}{l_t} \right)^\theta \right) \left( \sum_i p_i A_{it} \frac{l_{it}}{l_t} \right) \right)^{\frac{1}{\nu}}.$$

There are three terms here. The first is a constant. The second is the aggregate effective capital to labor ratio. In the case of Korea, this ratio grows after the crisis. Therefore, it cannot account for the fall in TFP after the crisis. The third term is our term for approximate TFP. In the case under study, we have already shown that changes in this term are due primarily to movements from high productivity sectors to low productivity sectors. Labor reallocation in the data leads to changes in measured effort.

## Appendix D: Isolating The Effects of Sectoral Reallocation

As was mentioned in the text, in the experiment TFP partially falls because productivity in the investment sector  $TFP_{nt}$  falls. Measured productivity in this sector falls because interest costs are not considered in the measurement of value added. These costs rise with the crisis leading to a reduction in materials. Here we show how to isolate this effect and demonstrate that it is quantitatively small.

Recall that:

$$A_t = \frac{p_{c1997}y_{ct} + y_{nt} - p_{f1997}f_t - z_t}{(u_{ct}k_{ct} + u_{nt}k_{nt})^\theta (l_{ct} + l_{nt})^{1-\theta}}.$$

Value added in the manufacturing sector can be expressed as:

$$GDP_{nt} = TFP_{nt}(u_{nt}k_{nt})^{\alpha_{kn}} l_{nt}^{1-\alpha_{kn}},$$

where  $GDP_{nt} = y_{nt} - p_{f1997}f_t - z_t$ .

We can compute an alternative value added by holding productivity  $TFP_{nt}$  constant at its 1997 level and allowing utilization, capital and labor to vary:

Let

$$GDP_{nt}^{1997} = TFP_{n1997}(u_{nt}k_{nt})^{\alpha_{kn}} l_{nt}^{1-\alpha_{kn}}.$$

Using some algebra,

$$GDP_{nt}^{1997} = \frac{TFP_{n1997}}{TFP_{nt}} GDP_{nt}.$$

Thus we can define a TFP term with constant sectoral productivities as:

$$A_t^* = \frac{p_{c1997}y_c + \frac{TFP_{n1997}}{TFP_{nt}}(y_{nt} - p_{f1997}f_t - z_t)}{(u_{ct}k_{ct} + u_{nt}k_{nt})^\theta (l_{ct} + l_{nt})^{1-\theta}}.$$

In our full experiment detrended  $A_t^*$  fell 74.3% as much as  $A_t$ . From this we conclude that the fall in productivity in the investment sector is secondary for explaining the fall in TFP.

## References

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