Estimating Lost Output from Allocative Inefficiency, with Application to Chile and Firing Costs

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March 2010

Abstract

We propose a new measure of allocative efficiency based on unrealized increases in aggregate productivity growth. We show that the difference in the value of the marginal product of an input and its marginal cost at any plant - the plant-input "gap" - is exactly equal to the change in aggregate output that would occur if that plant changed that input's use by one unit. The mean absolute gap across plants for any input can then be interpreted as the gain to society that would occur if every plant had a one-unit change in that input in the efficient direction, holding everything else constant. We show how to estimate this average gap using plant-level data from Chilean manufacturing from 1982-1994, a sector largely viewed as being one of South America's least distorted. We find the gaps for blue and white collar labor are quite large in absolute value and increasing over time, and that a one-unit move in the correct direction for blue collar would increase aggregate value added by almost 0.5%. We find the gap for materials is small and the gap for electricity non-neglible but not robust. We also find that the timing of the two separate increases in firing costs - one in 1985 and one in 1990 - is suggestive that the increase in average within-firm labor gaps is related to the increases in severance pay. We find no evidence that gaps increase for inputs that are not directly affected by firing costs.

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1 Introduction

There are many phenomena that move an economy away from the neoclassical setup, where an input's value of marginal product is equated with its marginal cost. These include markups, hiring, firing and search costs, capital adjustment costs, taxes and subsidies, holdup and other contracting problems, and non-optimal managerial behavior. We develop a simple approach that uses production data to estimate the "gaps" between an input's marginal product and its cost, and use them to infer the value of lost output arising from allocative inefficiency.

We define allocative efficiency in terms of its impact on aggregate productivity growth (APG). A unit increase in any input raises APG by that input's concurrent value marginal product-input cost gap.[1] With common input costs across firms, output increases holding input use constant if inputs are *reallocated* from lower to higher marginal value activities. As an indicator of allocative inefficiency we look at the potential gain from additional adjustments in inputs that do *not* occur.

The gaps are the principal input into our calculation of lost output from allocative inefficiency. We show how plant-level or industry-level production data identifies the net output change when a unit of labor (e.g.) is reallocated from one establishment to another, or from being unemployed to being employed. We provide a framework for evaluating specific policy changes like increases in hiring or firing costs or more aggressive merger guidelines. We suggest isolating their impact by estimating gaps prior to and right after the policy change.

Our approach can readily be carried out in standard programming packages. Our estimates for the value of marginal products use estimates from production functions, for which there are a wide variety of estimators.[2] Production data also typically contains measurements on input expenditures, and we use these to approximate the marginal cost of each input.

We illustrate our approach using plant-level data from 1982-1996 in Chile, Latin America's fastest growing country. Many economists have attributed Chile's economic growth to the measures taken in the 1970s to reduce economic frictions. We look at the magnitudes of gaps at Chilean manufacturing firms across the periods 1982-1996.We find negligible gaps for materials across estimators. We find non-negligible gaps for electricity inputs, but they are not robust across estimators. Finally, we find large gaps for blue and white collar labor inputs that are robust. On average, the gaps for labor equal approximately one year's respectively salary

[1] See Petrin and Levinsohn (2009).

[2] Our Stata code, which is available to researchers, contains six different estimation approaches for production functions and illustrates how to construct estimate of the gaps from them.

for both blue and white collar. The finding implies that increasing labor by one unit at firms with positive gaps and decreasing labor by one unit at firms with negative gaps leads to an increase in value added of 0.5 %.

We then look for an impact on allocative efficiency of two *increases* in the cost of dismissing workers. [3] In 1984 Chile no longer exempted firms from severance pay when they could demonstrate "economic cause" for dismissal. Severance was set equal to no less than a month's wages per year of tenure, with a five month ceiling. In 1991 the ceiling increased to 11 months. We look at the gaps for blue and white collar labor right before and after the two policy changes. We find increases in the mean of *within-firm* gaps following increases in firing costs for both blue and white collar labor. All years after 1985 have average blue and white-collar gaps that are significantly different from every year prior to 1985, and the biggest jump in the gaps occurs right after the first increase in firing costs.

Economic theory says that a variety of changes can impact plant-level gaps and we want to try to isolate the impact of firing costs from other changes occurring in the economy. We show that different policies can have implications for gaps that vary across inputs and one can use these differences to try to isolate the impact of a policy change on allocative efficiency. Lemma 2 provides one result, showing that policies that impact adjustment costs for inputs like labor or capital *only* affect the marginal revenue product (MRP) gaps associated with those inputs. Inputs without adjustment costs should not have their gaps change, so these inputs can act as "controls."

We then look at the MRP gaps for materials and electricity right before and after the policy change. We find no evidence of any increase in the gaps for either materials or the electricity across the time periods. In summary, our approach identifies a significant fall in allocative efficiency for both blue and white collar labor in the 1980s, and both the timing of the gap changes and the fact that "freely variable" inputs did not experience MRP gap changes suggests at least part of the decrease in allocative efficiency may have occurred because of the increase in firing costs.

While Lemma 2 shows how other inputs can be used to develop a difference-in-

[3] Most of the empirical work on firing costs focusses on whether employment levels increase or decrease (see Heckman and Pages (2004)). The evidence has largely been mixed, probably because the theory says that firing costs, when they do have an impact, lead some firms to hold too much labor and others to hold too little. Depending upon the assumptions, some theory papers find a positive effect of increasing firing costs on employment (Bentolila and Bertola (1990), Alvarez and Veracierto (2001)), while others find a negative effect (Risager and Sorensen (1997), Bertola (1990), and Hopenhayn and Rogerson (1993)). Both Edwards and Edwards (2000), who use aggregate time-series data, and Pages and Montenegro (1999), who use individual-level employment survey data, find no effect of these increases on aggregate unemployment levels.

differences approach by using the non-labor inputs as controls, we further exploit variation across industries to formulate a difference-in-difference-in-differences (DDD) approach. In particular, the effects of the mandatory firing laws are likely to be the least binding in industries that exhibit *excess worker turnover*, defined as the total worker turnover over and above gross job turnover (Burgess et al. 2000). To the extent that worker turnover exceeds gross job flows, excess worker turnover is likely to be more prevalent in industries with greater voluntary worker separations.[4] Thus for these industries, adjustments to employment levels can be more easily made without relying on involuntary separations that trigger mandated severance payments. Using Quarterly Workforce Indicators (QWI) data for the US, we developed industry-specific measures for excess worker turnover. We then examine differences in the absolute gap changes for all inputs in the top and bottom quartiles of the excess worker turnover measure. As we would expect, we find systematically larger increases in the blue and white collar gaps for firms in the bottom quartile of the excess worker turnover distribution, relative to the top quartile, both in period 2 and period 3. In contrast, we find no such systematic differences between the samples in the case of the materials and electricity gaps.

Our approach is closest in spirit to Hsieh and Klenow (2009) and Basu and Fernald (2002), and it is also related to the wide collection of definitions of reallocation from Baily, Hulten and Campbell (1992) (BHC) and its derivatives (e.g. Olley and Pakes, (1996), and Foster, Haltiwanger and Krizan 1998).[5] The main difference between our definition of reallocation and all of these variants is that these alternative definitions do not sum changes at the plant-level up to a standard aggregate productivity growth measure, whereas our accounting framework is designed entirely with that criterion in mind.

The paper proceeds as follows. Sections 2-4 develop the reallocation framework and estimation methodology. Section 5 summarizes the key economic reforms in Chile over the period that we examine (1982-1996). Section 6 describes the plant-level data. Section 7 and 8 describe details of estimation and results, and Section 9 concludes.

[4] Our checks using more aggregated (2-digit SIC level) data for an earlier period (1958-1979) from Ragan (1984, Table 2) show that the excess turnover measure is indeed highly correlated with the quit rate – correlation of 0.81, p-value¡0.01% (see also footnote 24).

[5] See also Caballero and Engel (1993) and Caballero and Engel (1999), who demonstrate the existence of fixed costs of adjustment for capital.

2 Measuring Lost Output Due to Allocative Inefficiency

We use the accounting framework from Petrin and Levinsohn (2009) to derive aggregate productivity growth from the micro-level and derive the reallocation terms. Readers not interested in the details can skip to Section 2.1 and then directly to implementation in Section 4.

We assume there are at most N plants in the economy each of which produces one good.[6] Each plant i's production technology is given by

$$Q^i(X_i, M_i, \omega_i), \tag{1}$$

where $X_i = (X_{i1}, \ldots, X_{iK})$ is the vector of K primary input amounts (types of labor and capital) used at plant i, $M_i = (M_{i1}, \ldots, M_{iJ})$ is the vector giving the amount of each plant j's output used as an intermediate input at plant i, and ω_i is the level of plant i's technical efficiency. F_i is equal to the sum of all fixed and sunk costs at i and we normalize these costs to the equivalent of the forgone output and deduct them, letting $Q_i = Q^i(X_i, M_i, \omega_i) - F_i$. The total amount of output from plant i that goes to final demand Y_i is then

$$Y_i = Q_i - \sum_j M_{ij},$$

where $\sum_j M_{ij}$ is the total amount of i's output that serves as intermediate input within the plant and at other plants.

We operate in continuous time (suppressing t), so the the differential for i's final demand is given as $dY_i = dQ_i - \sum_j dM_{ij}$. Letting P_i denote the price of plant i's output, aggregate productivity growth (APG) is the difference between the change in aggregate final demand and the change in aggregate costs:

$$PL \equiv \sum_i P_i dY_i - \sum_i \sum_k W_k dX_{ik}, \tag{2}$$

where W_k equals the unit cost of the kth primary input and dX_{ik} is the change in the use of that primary input at plant i, and the summation is taken over all plants.

When Q_i is differentiable equation (2) can be decomposed as follows:

$$\sum_i \sum_k (P_i \frac{\partial Q_i}{\partial X_k} - W_k) dX_{ik} + \sum_i \sum_j (P_i \frac{\partial Q_i}{\partial M_j} - P_j) dM_{ji} - \sum_i P_i dF_i + \sum_i P_i \frac{\partial Q_i}{\partial \omega_i} d\omega_i, \tag{3}$$

[6] Any of the N products may potentially be used as an input in production. The setup extends to multi-product plants.

where $\frac{\partial Q_{(\cdot)}}{\partial X_k}$ and $\frac{\partial Q_{(\cdot)}}{\partial M_j}$ are the partial derivatives of the output production function with respect to the kth primary input and the jth intermediate input respectively, dM_{ij} is the change in intermediate input j at plant i, dF_i is the change in fixed and sunk costs, $\frac{\partial Q_{(\cdot)}}{\partial \omega_i}$ is the partial derivative of the output function with respect to technical efficiency and $d\omega_i$ is the change in technical efficiency at plant i. $\sum_i P_i \frac{\partial Q_i}{\partial \omega_i} d\omega_i$ are the gains from technical efficiency changes and $-\sum_i P_i dF_i$ is the value of lost output arising from any incurred fixed or sunk costs. The reallocation terms are given by the first two terms from (3).

2.1 Linking the Gaps to Allocative Efficiency

The reallocation terms are based on the value of the marginal products (VMP) for every input, given generically for any input X_k at firm i as:

$$VMP_{ik} \equiv P_i \frac{\partial Q_i}{\partial X_k}. \tag{4}$$

The reallocation terms include a VMP term and an input cost term for each plant and every primary and intermediate input:

$$\sum_i \sum_k (P_i \frac{\partial Q_i}{\partial X_k} - W_k) dX_{ik} + \sum_i \sum_j (P_i \frac{\partial Q_i}{\partial M_j} - P_j) dM_{ij}.$$

Using labor as an example, assuming common wages, reallocation of a unit of labor from j to i would lead $dL_i = 1$ and $dL_j = -1$, and would thus increase the value of output by

$$P_i \frac{\partial Q_i}{\partial L} - P_j \frac{\partial Q_j}{\partial L}$$

while holding total labor input constant. This thought experiment motivates the following measure of forgone output, which is written in terms of labor but can be applied to any input.

Lemma 1. *The average absolute gap across firms between labor's value of marginal product and wage equals the average productivity gain from adjusting labor by one unit in the optimal direction at every firm, holding all else constant.*

Proof. Define indicator variable D_i as the unit adjustment of labor in the optimal direction for firm i. Then:

$$D_i = \begin{cases} 1 & \text{if } P_i \frac{\partial Q_i}{\partial L} > W \\ -1 & \text{if } P_i \frac{\partial Q_i}{\partial L} < W \end{cases} \tag{5}$$

The average productivity gain from adjusting labor by one unit in the optimal direction is then:

$$\frac{1}{N}\sum_{i=1}^{N}\left(P_i\frac{\partial Q_i}{\partial L}-W\right)D_i=\frac{1}{N}\sum_{i=1}^{N}\left|P_i\frac{\partial Q_i}{\partial L}-W\right| \tag{6}$$

□

Equation (6) provides a simple lower bound measure to the potential efficiency gains to the economy from moving "one-step" in the direction of being more efficient.[7]

For counterfactuals we let $E0$ and $E1$ denote the two different states. For example, $E0$ might denote the state of the economy with firing costs and $E1$ might denote the economy after all firing costs have been eliminated. We use the path of the movements of inputs, outputs and prices between $E0$ and $E1$ over the interval $t \in [0,1]$.[8]

We use the reallocation terms to define the change in aggregate productivity growth due to changes in allocative efficiency:

$$\Delta AE \equiv \int_0^1 \sum_i \sum_k (P_{it}\frac{\partial Q_{it}}{\partial X_k}-W_{kt})dX_{kt}+\int_0^1 \sum_i \sum_j (P_{it}\frac{\partial Q_{it}}{\partial M_j}-P_{jt})dM_{jt} \tag{7}$$

As a simple example, consider the case of a single (labor) input firm facing an infinitely elastic labor supply curve. Suppose the firm starts from an economic environment ($E0$) where the firm has a gap positive between the VMP for labor and the wage, as illustrated in Figure 1. This gap could be due to any type of friction, including firing costs, or a tax on wages, or due to a markup charged by the firm. Eliminating the entire gap moves the firm to the socially optimal labor level L^*. The allocative efficiency gain would be equal to the area traced out below the VMP curve and above the wage curve.

[7] (6) is partial equilibrium in nature and assumes the economy is not constrained in a way that makes this labor reallocation impossible. It also does not include any real adjustment costs (like retraining) associated with the labor movements.

[8] We collect the path of primary and intermediate inputs and productivity shocks for firm i as $Z_{it} = (X_{it}, M_{it}, \omega_{it})$, $t \in [0,1]$. For the entire economy we write $Z_t = (Z_{1t}, Z_{2t}, \ldots, Z_{Nt})$. Given Z_t, output quantities are determined by the production technologies, and we write $Q_t = (Q_{1t}(Z_{1t}), \ldots, Q_{Nt}(Z_{Nt}))$. We assume prices are uniquely determined by Q_t, given as $P_t = (P_{1t}(Q_t), \ldots, P_{Nt}(Q_t))$, and similarly for primary input costs $W_t = (W_{1t}(Z_t), \ldots, W_{Kt}(Z_t)))$. We assume fixed and sunk costs for all i are deterministic given Z_t and its past values, and we collect these fixed costs in the vector $F_t = (F_{1t}, \ldots, F_{Nt})$. Y_{it} can then be directly calculated for all i and $t \in [0,1]$.

3 Input Demand with Adjustment Costs

We illustrate how market power and adjustment costs impact the allocative efficiency measure given in (7) using a simple dynamic model of input demand based on Bentolila and Bertola (1990). The production function is given as $Q(\omega_t, L_t)$ and is assumed differentiable, increasing and concave in labor L_t (the one input), and with demand/productivity shock ω_t. ω_t is stochastic so the firm is uncertain about future demand/productivity, and it is realized before the labor decision is made. Wages are exogenously set at W_t per unit of labor and there are linear, asymmetric hiring (H) and firing (F) costs given as:

$$C(dL_\tau) = (1_{[dL_\tau > 0]}H - 1_{[dL_\tau < 0]}F)dL_\tau.$$

We allow the firm to have some market power and assume monopoly pricing with current prices only a function of current output quantity, given as $P(Q_\tau)$. The firm then chooses an employment policy that maximizes the expected present value of profits over the future:

$$V_t \equiv \underset{L_t}{\text{Max}}\ E_t \left[\int_t^\infty e^{-r(\tau - t)} \{ (P(Q_\tau)Q(\omega_\tau, L_\tau) - W_\tau L_\tau) d\tau - C(dL_\tau) \} \right]. \tag{8}$$

Assuming the Marginal Revenue Product of labor is well-defined we have:

$$MRP^l = P\frac{\partial Q}{\partial L}\left(1 + \frac{Q}{P}\frac{\partial P}{\partial Q}\right) = VMP\left(1 + \frac{1}{\epsilon}\right),$$

where $\epsilon \equiv \frac{P}{Q}\left(\frac{\partial Q}{\partial P}\right)$ is the elasticity of demand. The solution to this maximization problem depends on the current demand shock and beliefs about their future path, and sets labor according to these beliefs to satisfy:

$$E_t \left\{ \int_t^\infty (MRP^l_\tau - W) e^{-(r)(\tau - t)} d\tau \right\} = -F \qquad \text{if } dL_t < 0 \tag{9}$$

$$-F < E_t \left\{ \int_t^\infty (MRP^l_\tau - W) e^{-(r)(\tau - t)} d\tau \right\} < H \qquad \text{if } dL_t = 0 \tag{10}$$

$$E_t \left\{ \int_t^\infty (MRP^l_\tau - W) e^{-(r)(\tau - t)} d\tau \right\} = H \qquad \text{if } dL_t > 0 \tag{11}$$

In this setting only when the firm faces an infinite price elasticity of demand and there are no firing costs will the value of the marginal product (VMP) be equated to the wage. Otherwise, none of the three conditions above have optimizing firms equating the value of the marginal product with marginal cost.[9] Instead, when

[9] Note that (9)-(11) show that it is not clear what cost shares provide an estimate of when there are adjustment costs, even in a setting without markups.

firing the firm chooses labor such that the discounted expected MRP^l given up is equal to the discounted cost of wages saved minus the firing cost. When hiring the firm chooses labor to equate the discounted expected MRP^l to the discounted cost of wages plus today's hiring cost. There are also a range of realized values for ω_t such that the firm does not adjust, in which case the difference between the discounted expected MRP^l and the discounted wage fall within the range [-F,H].

With markups but no firing costs, the optimal choice of labor in each period t equates marginal revenue with marginal cost, and the firm hires or fires in every period to exactly equate the marginal revenue product with the wage. A counterfactual that eliminated firing costs but not market power would calculate how allocative efficiency as measured by (7) improves as the economy moves from a setting where firms use the decision rules from (9)-(11) to the setting where firms choose labor equating $MRP^l = W$ in every period.

3.1 The Information in "Freely Adjustable" Input Gaps

Inputs without adjustment costs will have MRP gaps that respond to some changes in economic environments but not others, making them useful as "controls" for some questions. We extend the setup to consider the case of a 2-input production function that involves labor and another "freely adjustable" input M_t, with a unit price of P_t^m.

Definition 1. *An input M is defined as "freely adjustable" if $C(dM) = 0$.*

The new value function in equation (8) becomes:

$$V_t \equiv \underset{L_t, M_t}{\text{Max}}\ E_t \left[\int_t^\infty e^{-r(\tau - t)} \left\{ (P(Q)Q(L_\tau, M_\tau, \omega_\tau) - WL_\tau - P_\tau^m M_\tau) d\tau - C(dL_\tau) \right\} \right] \quad (12)$$

Lemma 2 gives the decision rule for M.

Lemma 2. *Assume $C(dM) = 0$ and $P(\cdot)$ and $Q(\cdot)$ are differentiable. Assume there exists a unique interior solution for M conditional on L. Then a profit maximizing firm equates the marginal revenue product of M to its marginal cost P^m conditional on the level of chosen labor.*

Proof. (12) is differentiable in M so profit maximization holds if and only if conditional on L the marginal revenue product of M is equal to the marginal cost of M. □

Optimization for labor choice yields the same conditions as in equation (9),(10), and (11), except that the expression for marginal revenue product for labor for any

L will be calculated conditional on the optimal level of materials for that given L. The key point is conditional on the chosen labor level the marginal revenue product of any "freely adjustable" input M will equal the contemporaneous marginal cost of that input.

The main implication for our approach is that a general change in the competitive environment that affects markups or a change in the tax on output will generally affect all input gaps, while a change in adjustment costs for one input will not affect the MRP gaps for inputs that do not have adjustment costs. Thus if VMP gaps on labor (e.g.) increase but MRP gaps on electricity and materials do not, whatever is affecting allocative efficiency of labor is unrelated to a change in markups or taxes on inputs or output.

4 The Gap Methodology

We start with a Cobb-Douglas production function specification in order to estimate marginal products. We write the function as:

$$q_{it} = \beta_s l_{it}^s + \beta_u l_{it}^u + \beta_k k_{it} + \beta_m m_{it} + \beta_e e_{it} + \beta_v v_{it} + \varepsilon_{it} \tag{13}$$

where q_{it} is the log of the real output, m_{it} is log of real value of intermediate materials, l_{it}^s is the log of the number of skilled (white collar) employees, l_{it}^u is the log of the number of unskilled (blue collar) employees, k_{it} is the log of the real capital stock employed, and v_{it} is log of the services used by firm i in year t. The productivity shock is given as

$$\varepsilon_{it} = \omega_{it} + \eta_{it},$$

with ω_{it} representing a transmitted component and η_{it} representing an iid (unexpected) productivity shock.

Given values for the production function (which we estimate in several different ways) and observed input levels, the marginal product is given for skilled labor (e.g.) by:

$$\frac{\partial Q_{it}}{\partial l^s} = \beta_s e^{\varepsilon_{it}} (l_{it}^s)^{\beta_s - 1} (l_{it}^u)^{\beta_u} (k_{it})^{\beta_k} (m_{it})^{\beta_m} (V_{it})^{\beta_v} (e_{it})^{\beta_e} = \beta_s . \frac{Q_{it}}{l_{it}^s} \tag{14}$$

Multiplying this marginal product by the plant's output price yields the value of the marginal product VMP_{it}^s.

The absolute value of the gap between the value of the marginal product and marginal input price for skilled and unskilled labor, G_{it}^s and G_{it}^u, and for materials

G^m_{it} and electricity G^e_{it} are given by:

$$G^u_{it} = |VMP^u_{it} - w^u_{it}|$$

$$G^s_{it} = |VMP^s_{it} - w^s_{it}|$$

$$G^m_{it} = |VMP^m_{it} - P^m_{it}|$$

$$G^e_{it} = |VMP^e_{it} - P^e_{it}|,$$

where w^u_{it} and w^s_{it} denote the wage rate for unskilled (blue-collar) and skilled (white-collar) labor respectively, P^m_{it} is the price for materials and P^e_{it} is the price for electricity.[10] These gaps are in nominal terms, so we deflate using the consumer price index, giving:

$$\text{Absolute real gap } \equiv RG_{it} = \frac{|G_{it}|}{CPI_t}$$

We also posit and estimate the parameters of a Cobb-Douglas revenue function, and using the estimated parameters, we construct estimates of the gap between MRP and input prices. A sufficient condition for a Cobb-Douglas revenue function to hold is to have an iso-elastic demand curve and a Cobb-Douglas production function. With an iso-elastic demand curve of the form $P_{it} = A_{it}Q_{it}^{\frac{1}{\epsilon}}$, and a production function as in (13), the parameters of the revenue function have form $\beta'_j = \beta_j\left(1 + \frac{1}{\epsilon}\right)$:

$$r_{it} = \beta'_s l^s_{it} + \beta'_u l^u_{it} + \beta'_k k_{it} + \beta'_m m_{it} + \beta'_e e_{it} + \beta'_v v_{it} + \varepsilon'_{it} \tag{15}$$

The procedure to estimate these parameters is very similar to that used to estimate the production function parameters, except that here we used the revenue directly (deflated by a CPI to improve comparability over time).

5 The Chilean Job Security Reforms

Firing costs are pervasive around the world (see Figure 2, which is taken from Heckman and Pages (2004)) and theoretically it is an open question as to whether they have any impact on economic efficiency.[11] In Chile workers have traditionally been provided with job security through three means: advance notices for

[10] These gaps are linear in the value marginal product and the wage. In terms of rates of convergence, $\sqrt{n}$ consistency of the gap follows directly from $\sqrt{n}$ consistency of estimators for each of these components, which has been established for the most commonly used production function estimators.

[11] Lazear (1990) shows how the distortion introduced by these provisions can potentially be completely undone by efficient contracts, where the mandated firing costs are passed on to workers who willingly accept a lower wage. In Appendix A we look carefully at Lazear's critique in the context of Chile.

dismissal, limitations on the use of fixed-term labor contracts, and severance payments on dismissal.[12] Over the 1981-1994 sample period, advance notice was unchanged at one month, and we know of no evidence of significant changes in the use of fixed-term contracts. Severance payments did change substantially on two occasions, particularly for workers that were fired for "economic" reasons. We look at these changes for evidence of an impact on economic efficiency.

There are two types of fired workers in Chile, those fired "justly" and those fired "unjustly." "Just cause" was defined in the Immobility Law of 1966, and it stated that criminal behavior and absenteeism (for example) qualified as reasons to fire someone without paying severance. Under this law economic and financial needs were technically "just."

In 1978, the Pinochet administration started requiring firms to pay one month's wages per year of service, subject to no upper limit, for any worker dismissed for "unjustified reasons." The *Labor Plan* of 1980 formalized this arrangement, mandating that severance packages be part of the overall job contract negotiated between the employee and the employer. It applied to all labor contracts signed after August 1981, and it restricted the minimum severance package for "unjustified reasons" to one month's wages per year of service, subject to a maximum of five months.

The first significant enhancement in job security during the sample period occurred in June 1984, when economic and financial needs were reclassified to "unjustified." Then, in December 1990, the new democratic regime strengthened the provision. While technically reclassifying firings for economic and financial difficulties as "just," the severance package for unjust firings became the package for "just" firings, and it was further strengthened by raising the maximum severance package from five to eleven months' wages, one month per year employed. The law also charged the employer a further 20% penalty when economic cause could not be established to the satisfaction of the court.

Pagés and Montenegro (1999) construct the following index for the expected present value of the firing costs associated with hiring a laborer:

$$C_t = \sum_{s=1}^{T} \beta^s \delta^{(s-1)} * (1-\delta) * \left(b + a_t S_{t+s}^J + (1-a_t) S_{t+s}^U\right),$$

with β denoting the discount factor, δ the probability of retention, b the cost of advance notice, a_t the probability that economic difficulties of the firm are considered "just," S_{t+s}^J the payment under justified cause, and S_{t+s}^U the payment

[12] This section draws heavily from the comprehensive treatment given in Edwards and Edwards (2000).

under unjustified dismissal. $\delta^{(s-1)} * (1-\delta)$ then equals the probability of firing at year s and $\left(b + a_t S^J_{t+s} + (1-a_t) S^U_{t+s}\right)$ is the expected cost associated with firing at that time.[13]

Figure 3 is calculated using their best estimates for a firm in Chile and it shows that firing costs in the pre-1984 period were low, close to 0.75 months of wages, and were primarily determined by the cost of advance notice.[14] Expected discounted cost increased to 2.2 months wages after the first reform in mid-1984, and then again to 3 months wages after the second reform. To put this into context for 41 OECD and Latin American countries together, Chile went from having one of the smallest levels of firing costs to being above the sample median of 2 months wages, although remaining well below the 10-14 month range of Colombia, Brazil, Peru, and Ecuador (see Figure 2).[15]

6 The Data and Variables

6.1 Data

We use the annual Chilean Manufacturing Census (Encuesta Nacional Industrial Anual) conducted by the Chilean government statistical office (Instituto Nacional de Estadistica). The survey covers all manufacturing plants in Chile with more than 10 employees and has been conducted annually since 1979. There are about 5000 firms every year, with an entry rate and exit rate of about 5 percent over the panel period. We use data on the 1982-1994 period in our analysis of the gaps. Starting our analysis in 1982 eliminates the effects of the large downturn in manufacturing in 1981 (see Appendix Figure A.3).

This survey has been used in a number of previous studies.[16] The survey pro-

[13] A more comprehensive approach would have indices for both the firm and the worker, C_{ijt}, although this calculation would require matched employer-employee data.

[14] They assume β equal to 0.92, δ equal to 0.88, b equal to 1, a_t starting at 0.8, falling to 0 from 1985-1990, and then increasing in 1991 to 0.9, S^J_{t+s} zero until 1990 when it increases to one month's pay for every year worked up to 11 months maximum, and S^U_{t+s} at one month's pay for every year worked up to 5 month's maximum, for 1981-1990, and then increasing to 1.2 month's pay for every year worked up to a maximum of 11 months.

[15] There are a number of other political and economic changes taking place over the sample period, many of which have been analyzed elsewhere. The Labor Plan reduced payroll taxes substantially in 1981. Gruber (1997) reports that these reductions were fully passed on to wages with no effect on unemployment. The bargaining power of unions was relatively low through the 1980s under the military government, but increased under reforms introduced by the democratic regime in 1991. Using aggregate data and time series analysis, Edwards and Edwards (2000) find that reduction of payroll taxes and decentralization of bargaining increased labor market flexibility and contributed to a reduction in unemployment. Finally, there was a severe recession in 1982 related to the Latin American debt crisis and the fall in copper prices, a major Chilean export. The recovery was also quite remarkable, with wages increasing at 5% a year and unemployment falling from 17% to 5.5% in the post-recession period.

[16] See Levinsohn and Petrin (2003) and citations therein.

vides an industry indicator, and measures of output, inputs, wages, employment and investment. A detailed description of how the longitudinal samples were combined into a panel from 1979-1986 can be found in Liu (1991). We extended this to 1996 following broadly the procedure used by Liu. Further, we supplemented the raw data with 3-digit price series for output, machinery and inputs from other sources including IMF's IFS database, data on price indices obtained from the Chilean government statistical office, and also with data from Edwards and Edwards (2000) and Edwards and Edwards (1991).[17]

6.2 Output, Input and Price Measures

Plant-level real output is total revenue deflated with a 4-digit industry output deflator obtained from the Web site of the Chilean Government's statistical office. We see total person years for different types of laborers and aggregate into blue and white collar workers. Real materials and services are both aggregates at the plant-level, and each have their own 3-digit price deflator. Over 30,000 plant-year observations report zero fuel use, so we deflate fuels with its own aggregator and combine them with materials.[18] Services purchased include freight, insurance, rent, accounting, communications, advertising, and technical support. Real electricity input is the reported quantity of electricity purchased. Electricity price is defined as the value of electricity expenditures divided by the quantity of electricity purchased.

The real capital series is constructed using the perpetual inventory method. Data on book value of capital is available for the years 1980-81 and 1992-96. We use the same methodology as Liu (1991) to construct the capital series for all firms for which we have data on book value for 1980-1991. For other firms, we build capital series backward and forward using the data on book value available for 1992-96. As in Liu, we assume a 5% depreciation rate for buildings, a 10% depreciation rate for machinery, and a 20% depreciation rate for vehicles. We use a deflator for the construction sector to deflate investments in buildings and use a deflator for machinery to deflate investments in both machinery and vehicles. The capital series we use is constructed using the 1980 base year, where firms with missing values for this year are replaced using the capital series constructed using 1981, 1992, 1993, 1994, 1995 and 1996 in that order.

[17] We thank Andrés Hernando for providing us with some of these deflators.

[18] Results are robust to dropping these observations.

6.3 Wage Rate Measure

At each firm we observe the total wage bill for several types of laborers. The components of the wages are given as Wages, Bonus, Payroll Taxes, and Family Allowance Taxes. We divide the total wage bill by the number of workers to get the average wage, and we use this estimate of the average wage to approximate the marginal wage.

While there is not an explicit category for firing costs, our understanding is these costs appear in the wage bill when they are incurred by the firm.[19] For plants that fire workers, this causes the estimated average wage to be higher than the marginal wage. We estimate the average wage overestimates the marginal wage by only about 2.8%, which is small relative to the size of our estimated gaps.[20] We also we find approximately 70% of the estimated gaps for both blue and white collar labor are positive. For these plants, the error *reduces* the magnitude of the estimated gap relative to its true size.

We examine general trends in the average real wage rates in Figure A1 (obtained by deflating the wage rate in our plant-level data using the output deflator). From separate sources we have unemployment and inflation rates across the sample period in Figure A2 and manufacturing growth in Figure A3. We find that both blue and white collar real wages dropped until the mid 1980s and then grew through the late 1980s and early 1990s. The positive increase over most of the sample period occurs along with positive manufacturing growth in every year.

7 Estimation

There are some important issues that a researcher will confront in practice: estimation of production function parameters and simultaneity, functional form for production, observing revenues versus quantities, measurement error in estimated productivity, and estimation of input prices. We discuss each in turn.

A wide variety of production function estimators are available to researchers using plant-level (or industry level) panel data. We employ two estimators that protect, to different degrees, against correlation between inputs and productivity, a demonstrated problem in plant-level data (see e.g. Olley and Pakes (1996) (OP)).

[19] Dr. Cox-Edwards advised us on this point. Our results are robust to using only Wages and Bonus.

[20] We estimate the size of this error using an observed probability of firing of 39.2% (from Table 6 of an earlier version of our paper (Petrin and Sivadasan (2006)), an observed average fraction of workers fired given a firing spell of 17.9% (from Table 7 of Petrin and Sivadasan (2006)), and an average tenure of 5 years for workers, which leads to maximum payment for the first increase in firing costs. The product of these terms suggests that the estimated average wage overestimates the marginal wage by 2.8%.

Our preferred specification allows the transmitted part of productivity to follow a first order Markov process and potentially be correlated with input choices. We use the Wooldridge (2009) modification of the Levinsohn-Petrin (2003) (LP) methodology. Wooldridge develops the one-step (efficient) GMM formulation of the LP/OP estimators and notes that the overidentification conditions described in LP/OP can be used to address the identification critique from Ackerberg, Caves and Fraser (2006).[21] We prefer LP to OP because of the well-known lumpiness of investment in plant-level data. We also use a fixed effects estimator that allows plant-level productivity to vary over three time periods.

On functional form, in section 8.2 we show how to estimate the gaps using a trans-log specification of the production function. This allows for a richer structure for the the elasticity of output with respect to individual inputs.

As in many plant-level data sets we observe plant-level revenues and not prices and quantities separately. Two approaches have been proposed to deal with production function estimation in this case. One approach deflates plant-level revenues by an industry price-deflator and then uses deflated revenues as the dependent variable in the production function regressions. Production function estimates are consistent if inputs are not correlated with the deviation of the plant-level price from the industry price index. An alternative is to assume that demand takes a particular functional form and use that functional form to back out a price control, as in Klette and Griliches (1996). While both approaches have their weaknesses we follow the literature and use the former approach.

When constructing an estimate of the value of the marginal product in the face of this price measurement error, we use the entire error from the production function estimates. Since this includes the ratio of the plant-level price to the industry price, we then multiply this estimate by the industry price deflator so only the plant-level price times the marginal product remains. For example, with the Cobb-Douglas production specification considered in Section 4, for skilled labor when we use the entire error in the estimation of the marginal product, we get

$$\beta_s \left(\frac{P_{it} Q_{it}}{P_{ht}} \right) \left(\frac{1}{L_{it}^s} \right)$$

with P_{ht} the industry price deflator. We then multiply this by P_{ht} to recover the value of the marginal product.

Another issue relates to whether the estimated error from the production function is all productivity, or whether it also contains measurement error in quantity. When the estimate of the marginal product is undertaken, the "error" that should

[21] Since the methods are overidentified one can simply drop the moments which they suggest may be problematic.

be used is the part of the error that is productivity. In our baseline estimates, we condition on the full error term, but we also check robustness to estimating and conditioning on the predictable (transmitted) component of the error term.

Finally, input prices are sometimes reported in plant-level data, but more often one observes total expenditures on the inputs and total units of the input, so the average input price will often be used in place of the marginal price.

8 The Gap Results for Chile, 1982-1994

8.1 Baseline Results

Over the entire sample period we observe 46,358 gaps for blue collar, with 10,087 observations in the three-year period prior to the first reform (1982, 1983 and 1984), 19,985 observations in the period between the two reforms (from 1985-1990), and 16,281 observations in the four year period after the second reform (from 1991-1994). Before conditioning on plant-specific differences and other observed control variables, we analyze the unconditional means and medians of the gap distribution.

We work in levels - thousands of 1979 Chilean pesos per worker - so changes in the gap are comparable to the observed annual wage per worker. In our data blue collar workers are paid on average 77 thousand pesos a year and white collar workers are paid 158 thousand pesos a year. The average (median) unconditional gaps for blue collar labor across the three periods are 98 (35), 142 (47), and 143 (43) thousand pesos. The average (median) unconditional gaps for white collar labor across periods are 142 (67), 181 (81), and 204 (97) thousand pesos. Gaps for labor are thus not small at the outset of the sample period and they grow over time.

In Table 1, we summarize the changes in the gaps across the three periods for blue collar labor, white collar labor, materials, and electricity. In each column the absolute value of the gap for the input is the dependent variable. All regressions include two period-indicators for the different degrees of job security, one for 1985-1990, and one for 1991-1994. Columns 2, 4, 6, and 8 also include the industry output growth rate as a control for industry level demand shocks. We include plant fixed effects which allow for base-period plant-specific gaps, so the magnitudes of the period dummies are identified by within-plant variation in the mean gap over time.

From Lemma 1 we know that the average absolute gap for an input in any period is an approximate measure of the potential gain in productivity from a

unit adjustment of that input in the optimal direction. The results in Table 1 suggest that, in the base period, the potential gain from a unit adjustment in blue collar labor was 105 thousand pesos per year, and for white collar labor it was 158 thousand pesos per year. In the second period, potential gains from a unit adjustment for both the blue collar and the white collar gaps increase significantly, by 35 thousand pesos and 23 thousand pesos respectively. In the third period, the blue collar gap decreases slightly (by about 2 thousand pesos), while the the white gap increases further, by almost 11 thousand pesos relative to the second period. The longer tenure of white collar workers is consistent with a bigger change in response to the second increase in job security.[22] For the base period, a one-step move of blue-collar labor in the "right" direction leads to almost a 0.5% increase in value added.

Using the same regressions, Figure 4 more closely examines the statistical significance of the year-to-year indicator variables relative to 1984 for both the absolute value of the gap for blue and white collar labor. The two horizontal lines indicate the average level of the gap in 1984 for blue and white collar labor. Confidence intervals for yearly indicator variables that do not contain the line are significantly different from the 1984 level. All nine of the blue collar as well as white-collar year dummies after 1985 are significantly different from 1984.

The timing of the results are consistent with the timing of the job security changes. The labor gaps are fairly level for white collar employees in the pre-change period until 1985, when they increase in 1986-87 after the first application of job security. For blue collar, there are some increases in the gap in 1984 and 1985, but a bigger increase in 1986-87. The gaps decline somewhat by 1990 for both blue and white collar, but increase again in 1991, at the time of the second increase in job security (though this increase is smaller than the jump in 1986).

Per Lemma 2, if some other friction (such as output taxes) are the cause for the gap between VMP and labor input prices that we see in in Table 1, we should expect to see this friction to drive a gap between MRP and input prices. Assuming perfect competition, VMP that we examine in Table 1 should yield the same results as for MRP. In Table 2, rather than relying on the competition assumption, we look directly at the more relevant marginal revenue product gaps for materials and electricity, by regressing revenue deflated by CPI (instead of industry-specific deflators) on inputs (with simultaneity addressed by the same Wooldridge approach used in Table 1).

[22] Results are robust to log specifications, and the results are similar to what we report for the levels specifications. When working in levels, we replace the biggest 2.5% of the gaps with the value of the 97.5th percentile, and similarly for the smallest 2.5% of the gaps (i.e. we winsorize the observations by 2.5% on both tails).

Examining the VMP results in Columns 5-8 of Table 1 as well as the MRP results in Table 2, we find that in contrast to the patterns for labor inputs, there is no increase in VMP or MRP gap for either materials or electricity across the two periods 1985-1990 and 1991 on. More generally, the evidence suggests that phenomena that impact all gaps, like changes in markups or input or output taxes, did not appear to impact allocative efficiency much relative to the initial 1982-1984 period.

We compare the year-to-year timing of the changes in gaps across inputs. Figure 5 plots the coefficients on the year dummy variables that come from regressing the absolute value of the gap for the input on industry output growth rate (as a control for industry level demand shocks) as well as plant specific fixed effects which allow for base-year (1981) plant-specific gaps. Gaps for all inputs are normalized to 100 in 1984 for this comparison. The graph tells a story similar to the above tables, with labor input gaps increasing and materials and electricity gaps decreasing slightly.

8.2 Robustness Checks

8.2.1 Alternative Production Function Specifications

In this section, we check robustness of the baseline results to two alternative ways of estimating the production function.

First, we use the same specification as in equation (13), but estimate it using OLS fixed-effects estimation. This estimation solves the identification problem by imposing $\omega_{it} = \omega_{ip}$ where p stands for one of the three time periods (period 1 is 1982-1984, period 2 is 1985 to 1990, and period 3 is 1991-1994), so the portion of the error term that influences a plant's choices of inputs is constant for each period.

The results, presented in columns 1 to 4 of Table 3 are similar to those in the baseline Table 1. We find slightly larger increases for blue- and white-collar gaps in both periods. Contrary to the base case, we find a slight increase in the blue-collar gap, and a slight decline in the white-collar gap, from period 2 to 3. As in the base case, we find declines in the gap for both materials and electricity (not significant for the latter in period 2, same as in the base case).

One drawback of the Cobb-Douglas specification in equation (13) is that the elasticities of output with respect to individual inputs are restricted to be constant, and the elasticity of substitution between inputs is restricted to be one. As an

alternative, we consider the following second order translog specification:

$$q_{it} = \sum_j \beta_j X_{it}^j + \beta_{jj} X_{it}^{j\,2} + \sum_{j \neq k} \sum_k \beta_{jk} X_{it}^j . X_{it}^k + \varepsilon_{it} \tag{16}$$

where i indexes plants, t indexes years, j and k index the different inputs. We estimate the translog production function using fixed effects, again imposing $\omega_{it} = \omega_{ip}$ as for the fixed effects case above.

The gap results using the translog production function are presented in columns 5 to 8 of Table 3. Here we find broadly the same patterns as in the basecase (in Table 1). There is a significant increase in the average absolute gap for blue collar and white collar labor in period 2 relative to period 1. As in the base case, the gap in period 3 is somewhat lower than in period 2 for blue-collar labor, while there is a significant additional increase in period 3 for white-collar labor (32.75 thousand pesos versus 25.17 thousand pesos). The patterns for the control inputs contrast with those for labor gaps – there is significant decline in the gap for materials in period 2 and 3 relative to period 1, while there is no significant change for electricity across the periods. Overall, all specifications suggest a decline in efficiency reflected in an increase in potential productivity gain from unit adjustment of labor in the optimal direction. Consistent with the increases being driven by firing costs, we see no evidence of any increase in the gaps for non-labor inputs.

8.2.2 Using Transmitted Component of Productivity

In this section, we check robustness of the results to conditioning on different components of the productivity (error term) in estimating the marginal products of the different inputs.

As discussed in Section 4, if η_{it} arises essentially from measurement error (in either output or inputs), then this term should be eliminated from the productivity residual when estimating the marginal product. In order to eliminate η_{it} , we form an estimator for ω_{it} in the following way. First, we run the first stage regression of output on variable inputs as well as a polynomial in capital and the proxy variable, and obtain the predicted output level ($\hat{q_{it}}$)from this regression. This yields the output net of the unpredicted part of the productivity term η_{it}. Then we subtract the contribution of the inputs using the coefficient estimates obtained earlier, so that we get $\hat{\omega_{it}} = \hat{q_{it}} - (\hat{\beta}_s l_{it}^s + \hat{\beta}_u l_{it}^u + \hat{\beta}_k k_{it} + \hat{\beta_m} m_{it} + \hat{\beta}_e e_{it} + \hat{\beta}_v v_{it})$.

The results conditioning on estimated ω_{it} are presented in Columns 1 to 4 of Table 4. These are qualitatively similar to that in baseline case in Table 1. For blue-collar labor, the effect is similar to the basecase for period 2 though slightly

lower for period 3 (25 thousand pesos relative to 34 thousand pesos). For white collar labor too, relative to the basecase, the change in average gap is similar for period 2 and slightly lower for period 3 (26 versus 33 thousand pesos) relative to the baseline case. The results for the materials and electricity inputs are qualitatively similar to the base case, with declines in the average absolute gaps in periods 2 and 3 relative to period 1.

8.2.3 A DDD Approach using Industry-level Excess Worker Turnover

In principle, differences in the nature of worker turnover across industries should lead to variation in the constraints imposed by the increases in mandatory severance payment. In particular, managers would have more flexibility to adjust employment levels without having resorting to layoffs in industries that have relatively high voluntary worker turnover. Firms facing negative shocks may be able to adjust employment levels downwards without having to resort to layoffs, and equivalently, firms facing positive shocks will be less hesitant in hiring workers as they are more likely to be able to adjust employment downward though voluntary quits in case the positive shock turns out to be temporary. Thus, if the increases in the gap for blue and white collar labor observed in Table 1 (and Figure 4) are indeed driven by the changes in firing costs, we expect these increases to be lower in industries that have higher voluntary worker turnover rates.[23] Combining this with our expectation that mandated severance payments should have no effect on the gaps for the freely adjustable materials and electricity inputs yields a difference-in-difference-in-differences (DDD) approach that we explore below.

We proxy for the extent of industry-level voluntary turnover using *excess worker turnover* from the US. Excess worker turnover is defined as the total worker turnover i.e. sum of all separations and hires, less the total job turnover i.e. the sum of the absolute changes in employment levels across establishments (Burgess et al, 2000). Gross job flows are likely to reflect required adjustments to the workforce (potentially driven by shocks to firm-level output demand or productivity). To the extent that worker turnover exceeds gross job flows, excess worker turnover is likely to be more prevalent in industries with greater voluntary worker separations.[24]

[23] For examples of similar sample-splitting tests, see Bond and Van Reenen (2007).

[24] We tried to obtain direct data on voluntary separations (or quits). Because the LEHD data does not track the reason for separations, direct data on voluntary separations (or quits) is not available in the QWI. Starting in 2000, the US Bureau of Labor Statistics has been conducting the Job Openings and Labor Turnover Survey (JOLTS) that does collate information by type of separation. However, per the BLS, the sample size (16,000 units) is too small for the Bureau to publish data at a disaggregated 3-digit (or even 2-digit) SIC level. The only publicly available data on quit rates disaggregated by industry that we were able to locate is from Ragan

Data on job and worker turnover are obtained form the quarterly workforce indicator database, which is based on data from the LEHD.[25] We collected data by 3-digit SIC code for 1995, which we cross-linked with the ISIC based industry classification in the Chilean data using a concordance between the SIC 3-digit code and the ISIC 3-digit code.

The results from splitting the sample into the top and bottom quartiles of the excess worker turnover measure are presented in Table 5. Examining the changes in gaps for blue-collar and white-collar worker (in Columns 1 and 2), as expected, we find that the increases are bigger in magnitude in the bottom quartile of the excess worker turnover distribution. This pattern holds for both period 2 and period 3, and for both blue and white collar workers. Looking at the results for materials and electricity (columns 3 and 4), again consistent with Lemma 2, we do not find systematically larger increases in gap for the firms in the bottom quartile of the excess worker turnover distribution, in either period 2 or period 3.[26]

Our approach assumes that the excess turnover measure represents a stable industry characteristic. Comparing the SIC 3-digit excess turnover measures for 1995 to that for 2001 in the US data, we find that they are very highly correlated (correlation 0.935). The very high correlation with average industry quit rates for 1958-79 period from Ragan (see discussion in footnote 24 above) further confirms that the excess turnover measure is indeed a stable industry characteristic.[27]

We interpret these results as strongly suggesting that the increases in gap observed for blue and white collar labor are indeed associated with the increases in firing costs mandated in 1985 and 1991.

(1984, table 2). These figures, presented for 2-digit SIC codes is based on a discontinued BLS labor turnover survey (Utter, 1982), were average rates for the period 1958-1979. We found very high correlation between the excess turnover from the QWI and the quit rate in Ragan (1984) – the correlation was 0.81, and significant at 0.01%. Also, the definitions of the top and bottom quartiles per the two measures overlapped significantly, and the results we got from defining quartiles using the cruder quit rate data from Ragan yielded qualitatively similar results (see Appendix Table A.2).

[25]The QWI database by SIC code is available at http://lehd.did.census.gov/led/datatools/qwiappssic.html. Detailed documentation on the LEHD files and the construction of the quarterly workforce indicators, is presented in the technical paper by Abowd et al (2005).

[26]The differences in number of observations between the top and bottom quartiles is driven by tied values for certain large industries in the top quartile that therefore get included in the top quartile. Results (available on request) are qualitatively very similar if we examine the top one-third versus the bottom one-third of the sample, and in that split the number of observations are closer together.

[27]Our approach also assumes, as in Rajan and Zingales (1998), that industry characteristics measured for the US are also applicable in other country contexts. Violation of this assumption is likely to lead to measurement error on the industry characteristic for Chile, which is likely to bias in the direction of weakening our results.

9 Conclusions and Extensions

In this paper, we propose a new methodology to measure the impact of any type of friction that reduces allocative efficiency by driving a wedge or "gap" between the value of the marginal product (VMP) of an input and its marginal cost. We show that the mean absolute gap between the value of marginal product and input price is related to allocative inefficiency in terms of its impact on aggregate productivity growth. In particular, the mean absolute gap corresponds to the mean change in aggregate productivity from adjusting the input by one unit in the optimal direction.

We use the VMP-input price gap to examining allocative inefficiency in Chile, particularly focussing on the effects of two mandated increases in the costs of dismissing employees. In the context of adjustment costs for particular inputs, we show how gaps for other inputs could serve as controls to rule out changes from frictions such as output taxes and subsidies, or non-optimal managerial behavior, that could be expected to affect the gaps for all inputs, and not just labor.

We then propose a method to estimate this gap using plant-level production data. Our approach is simple, transparent, and can readily be carried out in standard programming packages on aggregate data or the large micro-datasets that are increasingly available for different countries and time periods. We discuss a number of estimation and measurement issues relating to the application of the method, and propose a number of robustness checks to address potential concerns.

We then apply this method to study Chile and the effects of changes in job security there. We find sizable gaps for blue and white collar labor even prior to the increases in firing costs. We also find statistically significant changes in the within-firm absolute gap between the marginal product of labor and the wage for both white and blue collar workers following increases in job security. We find little impact on gaps for materials and electricity arising from the firing costs.

This gap analysis is applicable to many economic questions beyond the effects of firing costs. Our plant-level gap statistic can be used to look for effects of any policy that introduces additional terms to the plant's first order condition. In terms of the allocative efficiency implications, if the gap is increasing, then willingness to pay and cost of production are getting further apart.

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Appendix A: Undoing the Distortion with Contracts

If there is efficient bargaining between the worker and the employer a contract can be written specifying a side payment from the worker to the firm that fully offsets the firing cost (Lazear (1990)). Consider one such scheme for the 2-period case with no discounting and a constant wage.[28] The firm pays w in period 1 to the worker, with the worker agreeing to set aside c until period 2. In period 2, if $\theta_2 < \theta_1$, each worker who is fired receives c. All retained workers receive $w + c$. If $\theta_2 \geq \theta_1$, then retained workers receive $w + c$ and new hires get w.

This contract allows the firm to pay firing costs out of the worker's salary from the previous period. The optimal choices of labor and the hiring and firing rule remain unchanged from the non-distorted setting. The marginal cost faced by the firm is w in each period regardless of whether the firm hires or fires. Workers' labor force participation choice is also unaffected, as they receive the same wage as in the regime with zero firing costs. Since no distortions are introduced into the market, efficiency means welfare continues to be maximized.

Lazear (1990) argues that the inefficiency may be difficult to undo using side payments for many practical reasons. In particular, workers must be willing to make the side payments to the employer or into an insurance fund; apprehension on the part of workers regarding the future severance payment could prevent the distortion's undoing.[29] Also, from an efficiency standpoint, firing probabilities are dependent on worker characteristics and firm layoff experience, so any unemployment insurance plan that does not condition on these factors is not going to maximize welfare.

For an estimate of the per period reduction in wages required to offset the two job security changes introduced in Chile, we consider two "insurance" plans. Under the first, expected firing costs are recovered through premium payments over the lifetime of the worker in the firm. Under the second, the firm insures against the possibility of firing workers period by period.

A.1 Plan 1: Insuring over the worker's life time

Under this plan, wage premia are collected over the worker's tenure with the firm to offset the expected firing costs. The fair premia for worker j is given by α_j, a fraction of annual wages, and is calculated by setting the expected present value of the dismissal costs equal to the present value of the premia collected:

$$\sum_{s=1}^{T} \beta^s \delta_j^s (1 - \delta_j)(y_{j,t+s}) = \sum_{s=0}^{T-1} \beta^s \delta_j^s \alpha_j W_j$$

where β is the discount factor, δ_j is the probability of worker j being retained, $y_{j,t+s}$ is the severance cost in annual wages of firing worker j at end of s years, and T is the maximum tenure. Assuming that all workers in a firm have identical wages and dismissal probabilities, we can calculate the drop in wage levels (ie the premium payments) required to offset any increase in dismissal costs. We estimate how large the fall must be to offset the first job security reforms introduced in Chile, assuming the interest rate (for discounting) is 5% and the maximum tenure is 20 years.

[28] This contract can be written for the infinite-horizon case, with the firm and the worker agreeing to a similar arrangement period-by-period.

[29] Even if the workers are willing to make side payments, other problems exist, including potential moral hazard problems like workers attempting to obtain the severance package early, or agency problems like managers colluding with workers to extract excess severance payouts in the face of full insurance.

Current tenure	Dismissal rate	Implied wage change in year 1
all new	10%	**-3.09**%
all new	15%	**-4.25**%
all new	20%	**-5.19**%
all > 5 years	10%	**-4.17**%
all > 5 years	15%	**-6.25**%
all > 5 years	20%	**-8.33**%

A.2 Plan 2: Insuring period by period over the pool of workers

In this approach, the firm's expected firing cost for each period is insured by collecting a premium from all the workers of the firm. Assuming the same fraction of wages is collected from each worker, the fair premium in this case is obtained by setting:

$$\sum_{j=1}^{N_j} \delta_j y_j = \alpha \sum_{j=1}^{N_j} W_j$$

where δ_j is the probability of worker j being retained, y_{jt} is the severance cost in annual wages of firing worker j and N_j is the number of workers in firm j. Assuming that the workers in the firms are identical, we obtain the required drop in wage levels to pay for the insurance premia that offsets the first increase as:

Current tenure	Dismissal rate	Implied wage change in year 1
all new	10%	**-0.83**%
all new	15%	**-1.25**%
all new	20%	**-1.67**%
all > 5 years	10%	**-4.17**%
all > 5 years	15%	**-6.25**%
all > 5 years	20%	**-8.33**%

If workers are identical and $y_{j,t+s}$ is constant over all j (as in the case where the tenure of all workers exceeds 5 years), the premium payments are the same for both plans and given by $(1-\delta)y$.

Since we expect the current average tenure of typical firm to be between the extremes considered in the tables above, we guess that the fall in wages required to neutralize the Chilean 1984 dismissal cost might lie in the range of 3% to 6%. The second job security change increases the maximum dismissal cost from 5 months to 11 months, implying an additional drop that is similar in magnitude.

A.3 Empirical evidence on wages

To try to separate out the effect of job security changes on wages, we regressed the estimated plant-level average real wage on period controls for the job security changes. The other controls include firm fixed effects, firm output growth rate, industry output and industry growth rate, and the unemployment rate. Unfortunately, we do not observe worker-specific covariates.

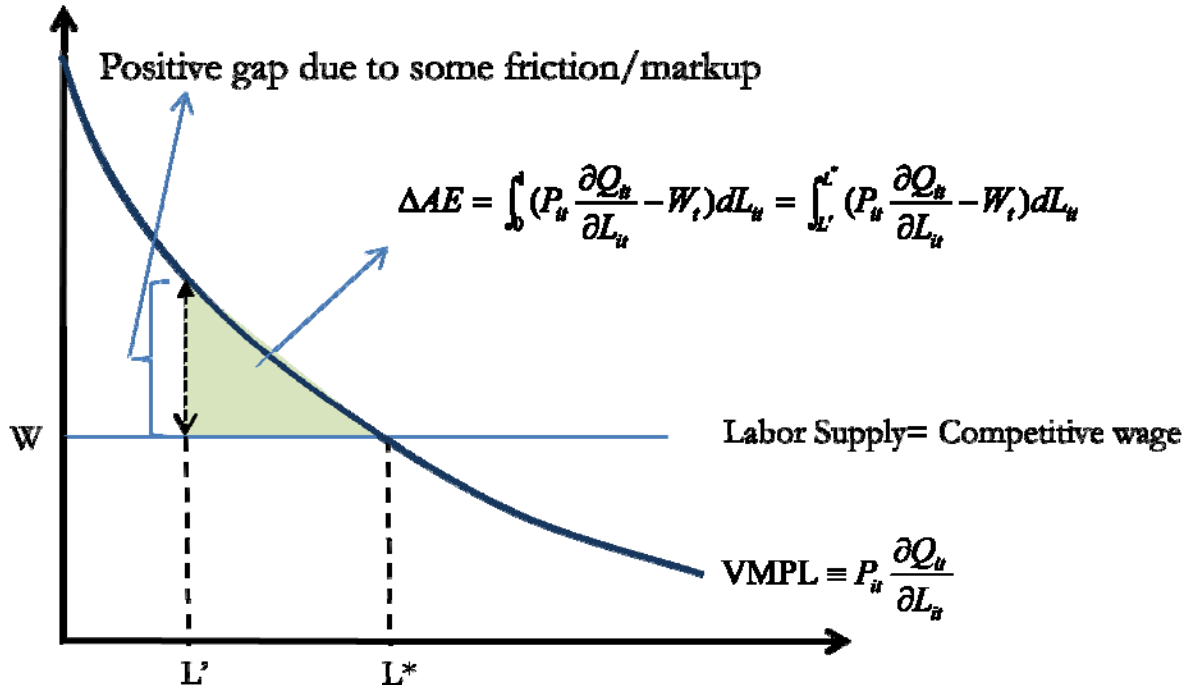
We report the estimates in Appendix Table A.2. In all the specifications, there is a major decline in wages in period 2 (1985-1990). The extent of the decline, between 36% and 53%, is much larger than that required under our offset plans. In period 3 wages recover somewhat. Overall, there is no clear evidence that the job security changes were offset through lower wage rates.

Appendix B: Wage Rate Variation within Blue/White Collar Categories

In our data there is variation in the wage rates across plants for both blue and white collar labor. If these differences exist because of market imperfections, then these wages are the marginal wages and there is no measurement problem. If they reflect differences in labor quality, then labor quantity is measured with error as it is not properly adjusted for unobserved labor quality.

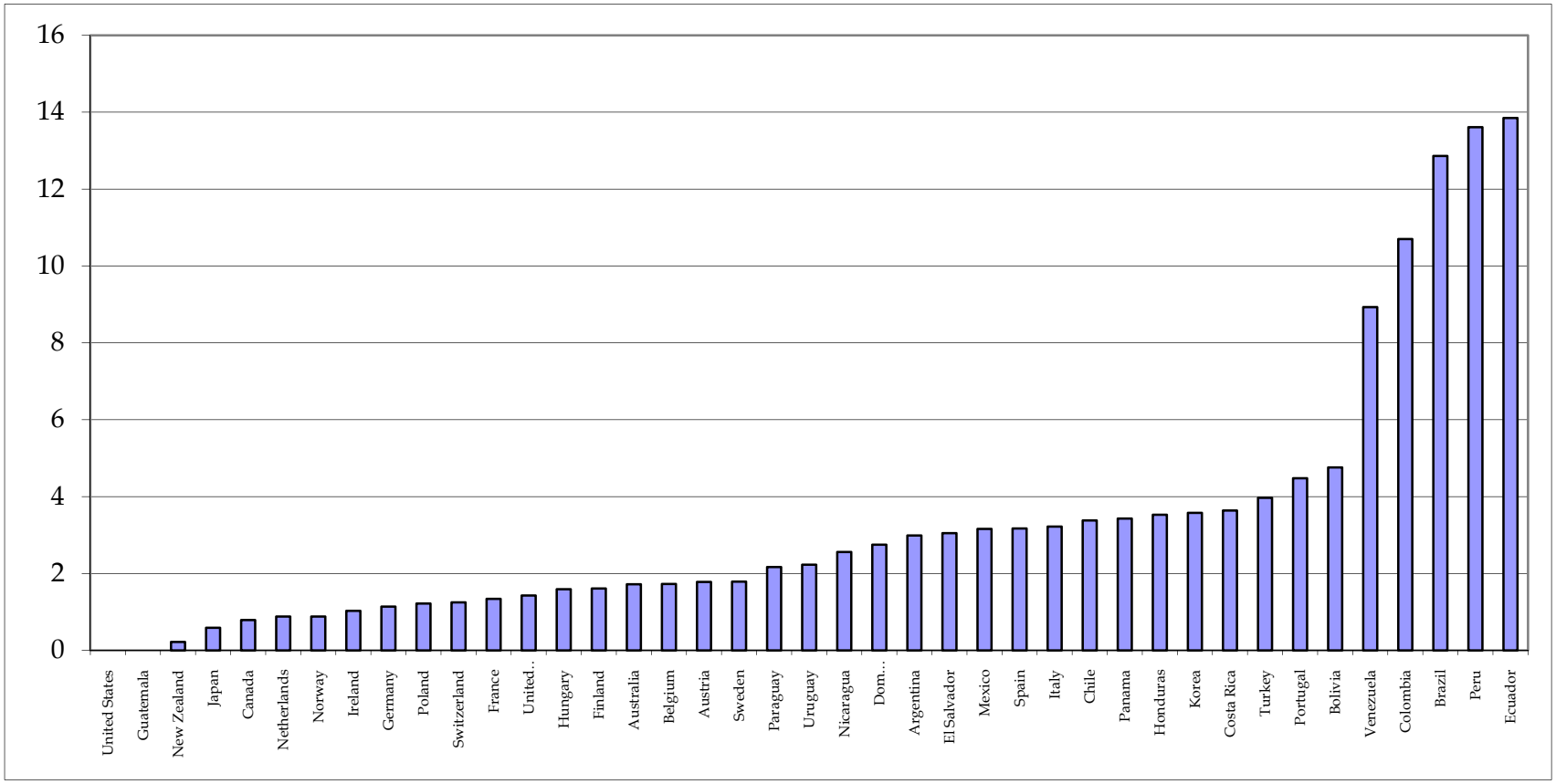
The potential bias in the measured gap may not be high, as measurement error on the wage side is offset by a higher measured marginal product per unit labor, as the firms with higher quality workers have higher estimated productivity levels. For example, consider firm A that employs half the workers as firm B, but of twice the quality level as firm B, and pays them twice the wage. Ideally, we may wish to use a quality adjusted measure for labor and wages for all firms. In the absence of this data, the measured wage for A will of course be higher than for B. But note that the measured productivity level will be higher for A which will increase the marginal product for A. Also, as noted above the fact that marginal revenue is declining in inputs means that the lower labor level at A will lead to a higher estimated marginal revenue product for A. Thus A has both a higher measured marginal revenue product, and higher measured wages, so the biases work to counteract each other. If the amount of measurement error in labor quality does not change in response to increases in firing costs then this error in the marginal revenue product is unlikely to vary in a way that would lead to finding larger gaps in periods of higher firing costs.

Figure 1
Allocative efficiency gain from eliminating a positive gap



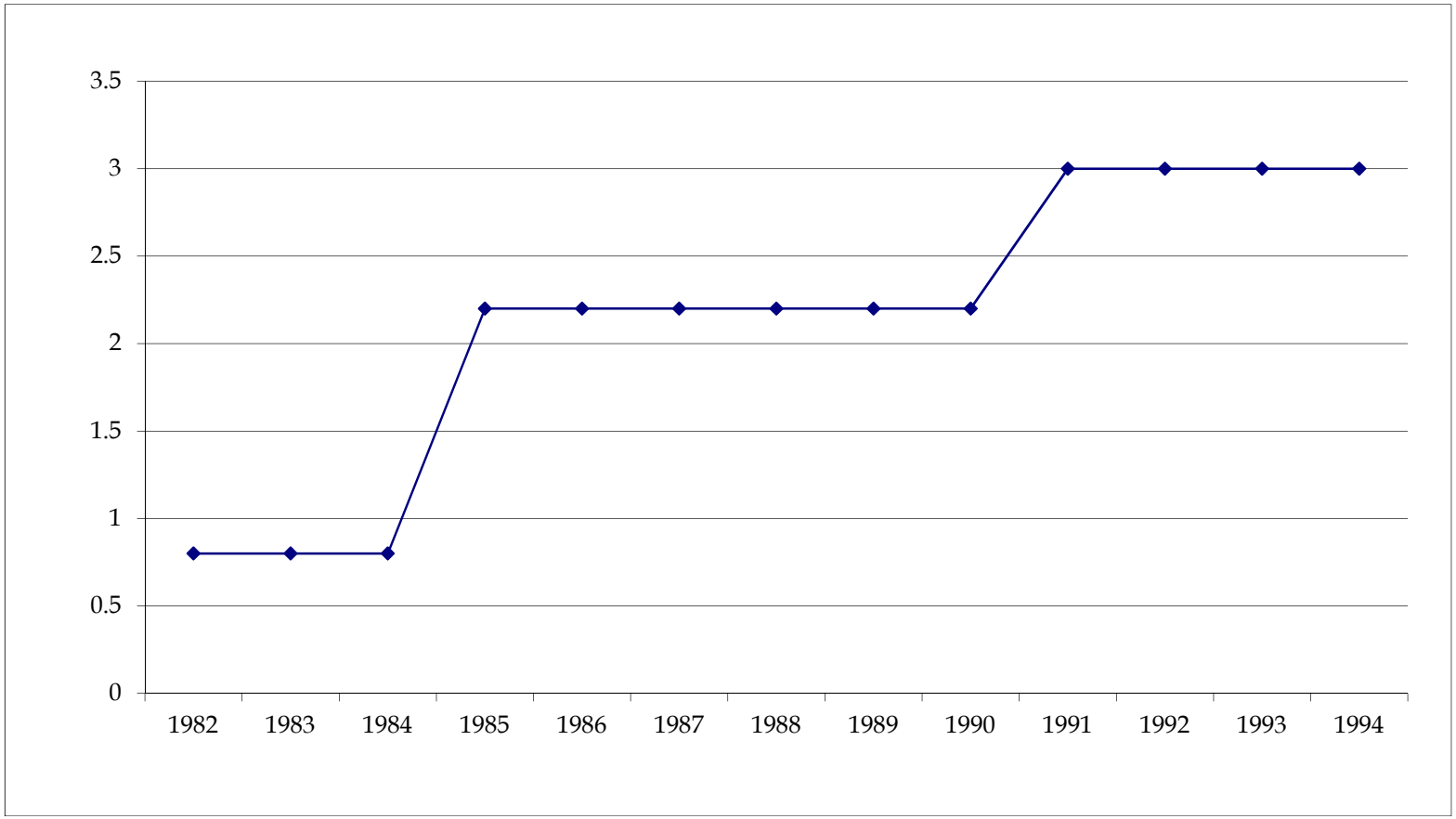
Suppose firm i starts from an environment with a positive gap (induced by say firing costs, or a tax on wages, or markup), so labor is L'. Moving to an environment with zero gap (i.e. labor level L*) yields increase in allocative efficiency equal to the area below the VMPL curve and above the wage line. In the case of a gap induced only by markup, the allocative efficiency area corresponds to the standard Harberger deadweight triangle.

Figure 2
Expected discounted cost of Firing a Worker
Multiples of monthly wages, Latin America and the IECD Countries, 1999



Source: Heckman and Pages (2004). Firing costs are defined as the additional payment made to the worker at the time of dismissal. This definition does not include ``indirect'' payments, like those made by U.S. firms into an insurance fund based in part on the number of firings at the firm.

Figure 3
The Change in Firing Costs in Chile
Expected discounted cost of dismissing a worker, in multiples of monthly wages



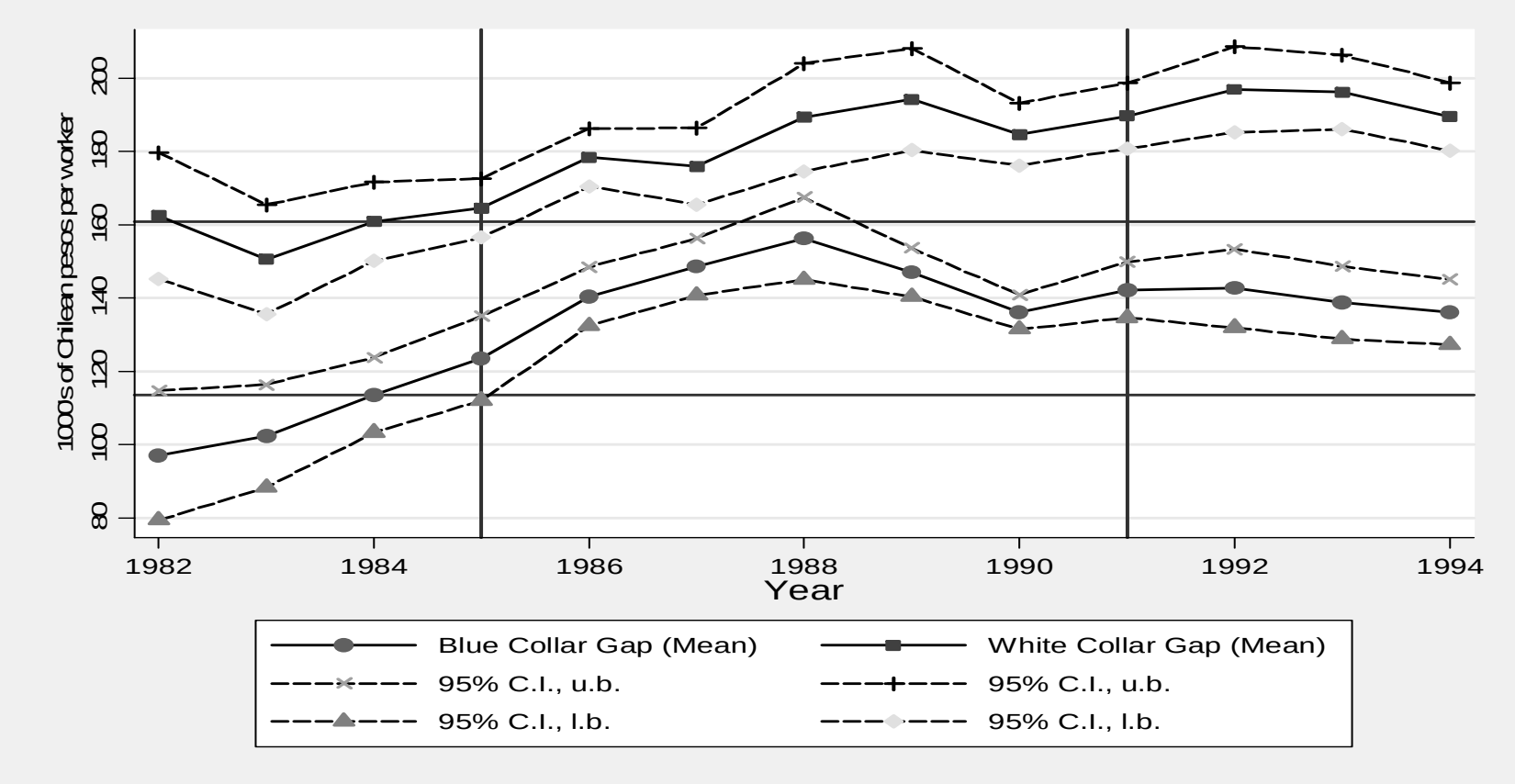
Source: Pages and Montenegro (1999)

Table 1
The Absolute Value of the Gap
Between the Value of Marginal Product and the Input Price, 1982-1994
Simultaneity-Corrected Production Function Estimates, All Specifications include Firm Fixed Effects

	Blue Collar		White Collar		Materials		Electricity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Base Period Gap (1982-1984)	105.3***	105.6***	158.1***	158.9***	0.405***	0.404***	39.97***	40.17***
	[6.393]	[6.404]	[6.667]	[6.556]	[0.0118]	[0.0119]	[1.154]	[1.160]
Increase in Gap, 2nd Pd. (85-90)	36.40***	35.99***	23.47**	22.41**	-0.0639***	-0.0623***	-0.998	-1.271
	[7.093]	[7.105]	[9.064]	[8.899]	[0.0157]	[0.0158]	[1.313]	[1.317]
Increase in Gap, 3rd Pd. (91-94)	34.36***	33.98***	34.71***	33.70***	-0.0325**	-0.0310**	-4.534***	-4.795***
	[10.04]	[10.07]	[9.432]	[9.323]	[0.0149]	[0.0152]	[1.705]	[1.718]
Industry Output Growth Rate		1.839		4.801*		-0.007		1.245
		[1.795]		[2.699]		[0.0166]		[0.928]
Observations	46,353	46,353	46,353	46,353	46,353	46,353	46,353	46,353
R-squared	0.82	0.82	0.73	0.73	0.53	0.53	0.64	0.64

All gaps are in thousands of 1979 pesos (deflator used is the CPI). Marginal product estimates are from a gross output (revenue deflated by industry-specific deflators) Cobb-Douglas production function specification, which is estimated using Wooldridge (2009) modification of the Levinsohn-Petrin (2003) approach to address the simultaneous determination of inputs and productivity. The blue-collar input price is the total blue-collar wage bill divided by the number of blue-collar employees. We define the white collar input price similarly. For materials we use a 3-digit industry-specific price index. Electricity prices are derived from establishment-specific quantity and value information. We estimate production functions separately for each 3-digit industry. Standard errors (reported in brackets) are clustered at the 4-digit industry level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Figure 4
Average Absolute Gap: Blue and White Collar Labor
95% Confidence Interval for Change in Gap



All gaps are in thousands of 1979 pesos (deflator used is the CPI). Gaps are those implied by the Wooldridge modification of the Levinsohn-Petrin Estimator. The figure plots the coefficients from the regression of the absolute value of the gaps on yearly indicator variables, plant-level fixed effects, and the industry output growth rate. The two lines demark the level of the average gap for blue and white collar labor in 1984, so the years for which the line is not within the confidence interval are the years for which the change in the gap is significantly different from the 1984 gap. Standard errors are clustered at the 4-digit industry level.

Table 2

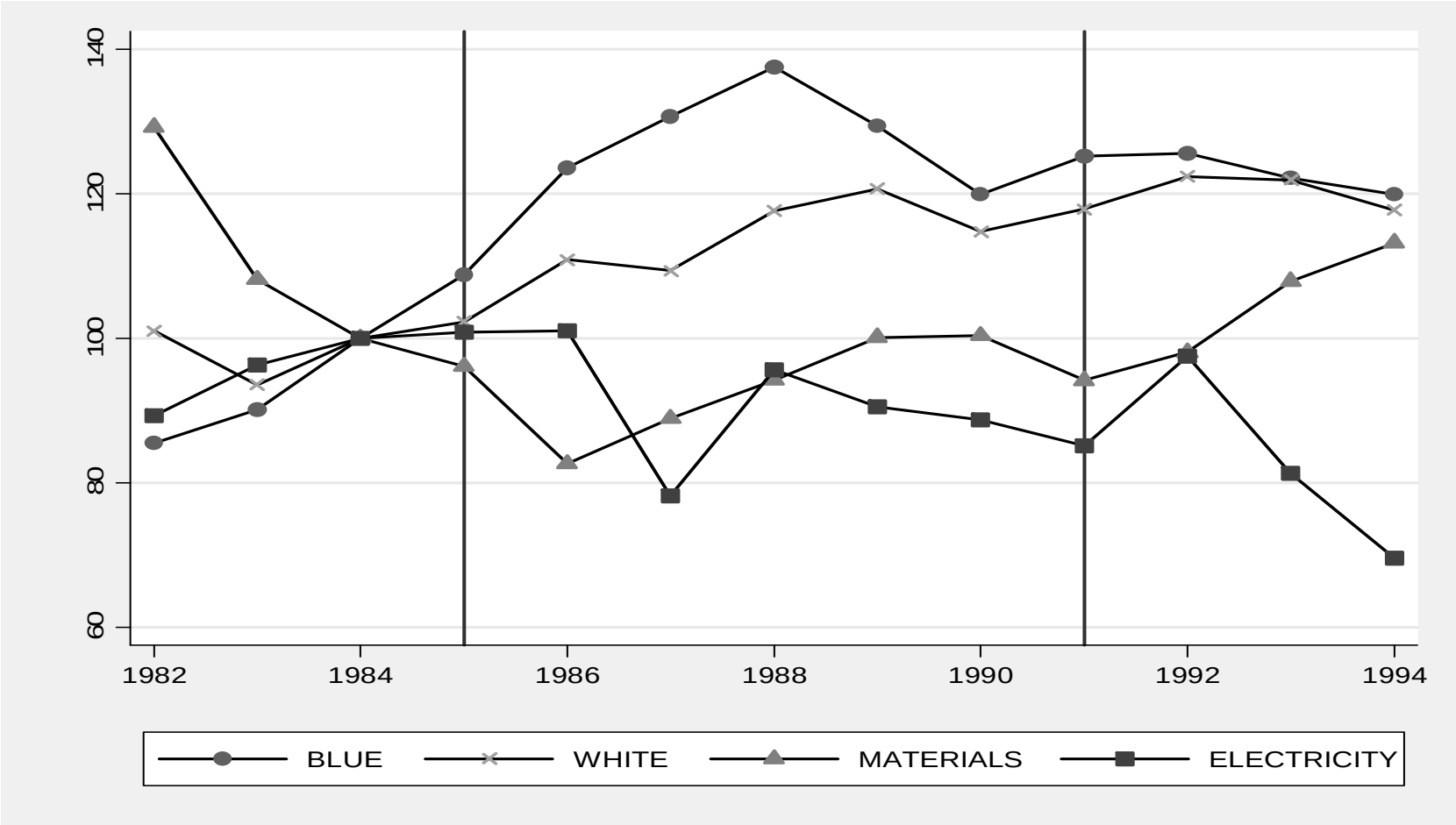
The Gap between the Marginal Revenue Product and the Input Price, 1982-1994

Simultaneity-Corrected Revenue Function Estimates, All Specifications include Firm Fixed Effects

	Materials		Electricity	
	(1)	(2)	(3)	(4)
Base Period Gap (1982-1984)	0.357***	0.356***	55.75***	56.01***
	[0.00637]	[0.00634]	[1.834]	[1.850]
Increase in Gap, 2nd Pd. (85-90)	0.00224	0.00297	-1.579	-1.937
	[0.0118]	[0.0117]	[1.946]	[1.956]
Increase in Gap, 3rd Pd. (91-94)	-0.0292***	-0.0285***	-6.018**	-6.359**
	[0.0103]	[0.0103]	[2.518]	[2.536]
Industry Output Growth Rate		-0.00334		1.626
		[0.00658]		[1.243]
Observations	46,353	46,353	46,353	46,353
R-squared	0.468	0.469	0.606	0.606

Marginal revenue product estimates are from a Cobb-Douglas revenue (deflated by CPI) function specification, which is estimated using Wooldridge (2009) modification of the Levinsohn-Petrin (2003) approach to address the simultaneous determination of inputs and productivity/demand. All gaps are in thousands of 1979 pesos (deflator used is the CPI). In all cases, we estimate revenue functions separately for each 3-digit industry. See notes to Table 1 for definitions of input prices. Standard errors (reported in brackets) are clustered at the 4-digit industry level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Figure 5
Trends in the Average Absolute Gap (Normalized)
Blue and White Collar Labor, Materials, and Electricity



The graph plots the coefficient on year dummies in regression of absolute gap between marginal product of an input and its normalized price. Gaps are those implied by the Wooldridge modification of the Levinsohn-Petrin Estimator. The regressions include firm fixed effects and industry output growth rate. Year 1984 is normalized to 100.

Table 3

The Gap between the Value of Marginal Product and the Input Price, 1982-1994
Robustness to Alternative Production Function Specifications

Simultaneity-Corrected Production Function Estimates, All Specifications include Plant Fixed Effects

	Cobb-Douglas OLS Fixed Effects				Translog (Order 2) Fixed Effects			
	Blue Collar	White Collar	Materials	Electricity	Blue Collar	White Collar	Materials	Electricity
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Base Period Gap (1982-1984)	113.8***	165.3***	0.370***	15.26***	89.31***	146.2***	0.266***	15.76***
	[8.594]	[5.638]	[0.00997]	[0.484]	[4.367]	[5.695]	[0.006]	[0.537]
Increase in Gap, 2nd Pd. (85-90)	41.96***	35.72***	-0.0352**	-0.223	22.88***	25.17***	-0.023***	1.018
	[10.27]	[6.743]	[0.0157]	[0.570]	[5.687]	[6.496]	[0.007]	[0.638]
Increase in Gap, 3rd Pd. (91-94)	42.18***	32.18***	-0.0368***	-1.405*	18.86***	32.75***	-0.0180**	1.02
	[12.56]	[8.996]	[0.0115]	[0.713]	[5.811]	[8.511]	[0.008]	[0.820]
Industry Output Growth Rate	3.936	3.45	-0.0043	0.478	2.843*	5.667**	0.000	0.191
	[2.637]	[2.979]	[0.0141]	[0.370]	[1.476]	[2.369]	[0.009]	[0.554]
Observations	46,353	46,353	46,353	46,353	46,353	46,353	46,353	46,353
R-squared	0.793	0.663	0.526	0.610	0.721	0.646	0.525	0.575

All gaps are in thousands of 1979 pesos (deflator used is the CPI). In columns 1 to 4, the marginal product estimates are from a gross output Cobb-Douglas production function specification, which is estimated using OLS with plant-period fixed effects. In columns 5 to 8, the marginal product estimates are from a gross output Translog (order 2) production function specification, which is estimated using OLS with plant-period fixed effects. In all cases, we estimate production functions separately for each 3-digit industry. See notes to Table 1 for definitions of input prices. Standard errors (reported in brackets) are clustered at the 4-digit industry level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4

The Gap between the Value of Marginal Product and the Wages, 1982-1994

Robustness to using transmitted component of the error term

Simultaneity-Corrected Production Function Estimates, All Specifications include Plant Fixed Effects

	Using Transmitted Component of Error			
	Blue Collar	**White Collar**	**Materials**	**Electricity**
	(1)	(2)	(3)	(4)
Base Period Gap (1982-1984)	104.2***	157.3***	0.336***	39.84***
	[5.084]	[5.569]	[0.0123]	[1.099]
Increase in Gap, 2nd Pd. (85-90)	33.09***	19.99**	-0.0329**	-1.064
	[5.410]	[7.936]	[0.0140]	[1.208]
Increase in Gap, 3rd Pd. (91-94)	24.82***	26.11***	-0.0437**	-6.684***
	[8.309]	[7.596]	[0.018]	[1.693]
Industry Output Growth Rate	1.603	2.393	-0.0224**	0.572
	[1.419]	[2.661]	[0.009]	[0.970]
Observations	46,353	46,353	46,353	46,353
R-squared	0.839	0.741	0.642	0.656

All gaps are in thousands of 1979 pesos (deflator used is the CPI). Marginal product estimates are from a gross output Cobb-Douglas production function specification, which is estimated using Wooldridge (2009) modification of the Levinsohn-Petrin (2003) approach to address the simultaneous determination of inputs and productivity. To calculate the marginal product, in columns 1 to 4, the transmitted component of the error term is used, and in columns 5 to 8, the predicted (using a 3 order polynomial of the lag) transmitted component of the error is used. See notes to Table 1 for definitions of input prices. Standard errors (reported in brackets) are clustered at the 4-digit industry level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5

The Gap between the Value of Marginal Product and the Wages, 1982-1994

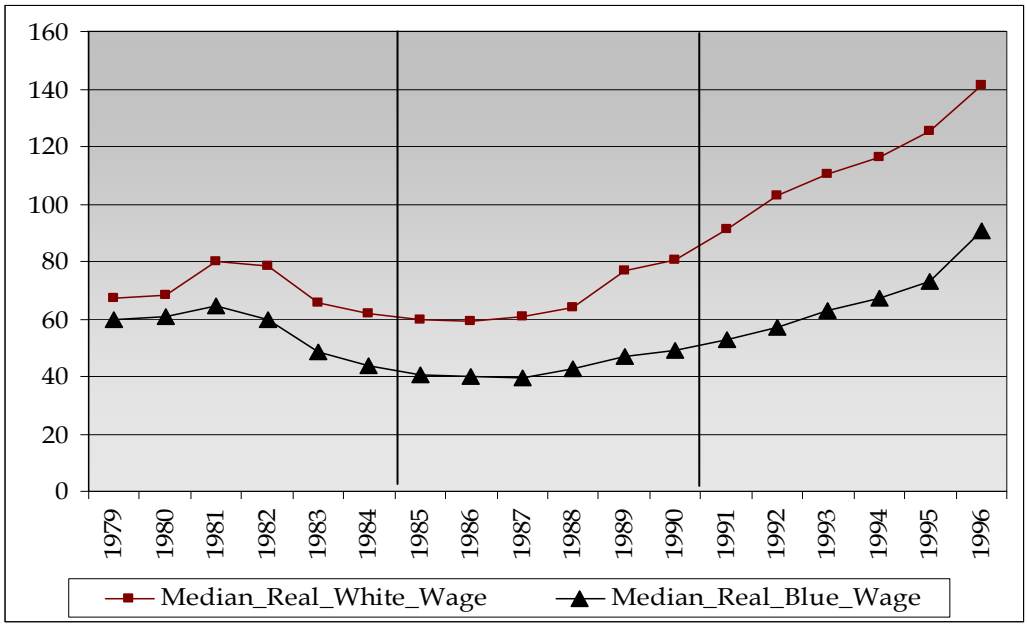
Sample-splitting Test based on Excess Worker Turnover

Simultaneity-Corrected Production Function Estimates, All Specifications include Plant Fixed Effects

	Blue Collar		White Collar		Materials		Electricity	
	Top quartile	Bottom quartile	Top quartile	Bottom quartile	Top quartile	Bottom quartile	Top quartile	Bottom quartile
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Base Period Gap (1982-1984)	62.15***	163.5***	126.1***	327.4***	0.482***	0.482***	19.27***	70.71***
	[5.977]	[14.30]	[8.423]	[16.29]	[0.0198]	[0.0170]	[0.778]	[3.565]
Increase in Gap, 2nd Pd. (85-90)	25.13***	66.32***	26.92***	54.61*	-0.087***	-0.052**	0.164	-2.106
	[5.158]	[13.88]	[9.210]	[26.85]	[0.0233]	[0.0237]	[0.833]	[3.645]
Increase in Gap, 3rd Pd. (91-94)	32.15**	78.38***	45.92***	66.50**	-0.043	-0.029	-0.605	-7.269
	[11.20]	[26.80]	[14.87]	[25.80]	[0.0288]	[0.0250]	[1.169]	[5.676]
Industry Output Growth Rate	-0.458	10.79	1.731**	22.49	-0.001	-0.0101	0.314	5.272
	[0.371]	[8.865]	[0.693]	[16.51]	[0.0163]	[0.0175]	[0.359]	[3.937]
Observations	14,063	9,207	14,063	9,207	14,063	9,207	14,063	9,207
R-squared	0.742	0.837	0.61	0.767	0.508	0.519	0.542	0.677

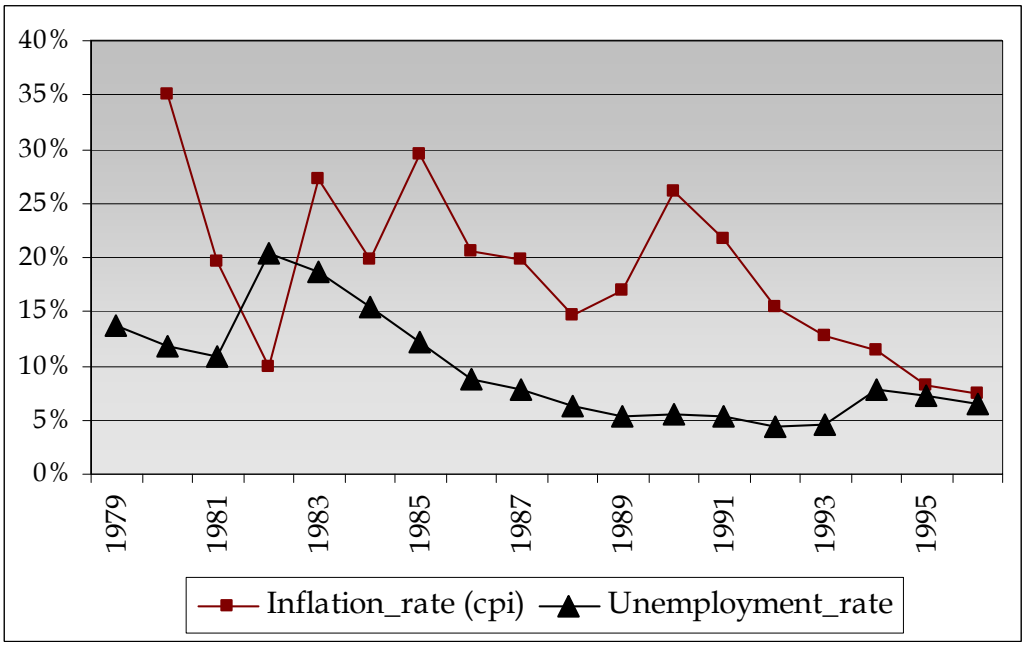
Excess worker turnover is defined as total worker turnover less job turnover normalized by employment, and is defined using 3-digit SIC code Quarterly Workforce Indicators (QWI) data for the United States. All gaps are in thousands of 1979 pesos (deflator used is the CPI). Marginal product estimates are from a gross output Cobb-Douglas production function specification, which is estimated using Wooldridge (2009) modification of the Levinsohn-Petrin (2003) approach to address the simultaneous determination of inputs and productivity. See notes to Table 1 for definitions of input prices. Standard errors (reported in brackets) are clustered at the 4-digit industry level. * significant at 10%; ** significant at 5%; *** significant at 1%.

Figure A.1
Trends in Real Wages



Source: Authors' calculations

Figure A.2
Inflation and Unemployment Rate



Source: Edwards & Edwards (2000), ILO statistics, authors' calculations

Figure A.3
Manufacturing Growth (From IMF IFS database)

Table A.1
Explaining Movements in Real Wages

	(1)	(2)	(3)	(4)	(5)
Period Dummy (1985-1990)	-0.37	-0.37	-0.40	-0.36	-0.53
	[0.02]**	[0.02]**	[0.02]**	[0.02]**	[0.02]**
Period Dummy (1991-1996)	0.081	0.072	-0.007	0.092	-0.112
	[0.02]**	[0.02]**	[0.02]	[0.02]**	[0.02]**
Firm Output Growth Rate		0.008			
		[0.002]**			
Log(Industry Output)			0.127		
			[0.021]**		
Industry Output Growth Rate				0.001	
				[0.006]	
Unemployment Rate					-2.131
					[0.19]**
Constant	4.49	4.52	2.52	4.48	4.81
	[0.014]**	[0.014]**	[0.319]**	[0.016]**	[0.026]**
Observations	86,176	73,701	86,160	80,346	86,176
R-squared	0.80	0.82	0.81	0.81	0.81

Dependent variable is Log (real wage rate). Real wage rate is the nominal wage rate deflated by the producer price index. Nominal wage rate is defined as the total wage bill/ number of employees. For each independent variable the first row gives the coefficient values and the second row gives the related t-values. All regressions include firm fixed effects. Standard errors are adjusted for clustering at the 4-digit industry level. + significant at 10%; * significant at 5%; ** significant at 1%.

Table A.2

The Gap between the Value of Marginal Product and the Wages, 1982-1994
Sample-splitting Test based on Quit Rate (Ragan 1984)

Simultaneity-Corrected Production Function Estimates, All Specifications include Plant Fixed Effects

	Blue Collar		White Collar		Materials		Electricity	
	Top quartile	Bottom quartile	Top quartile	Bottom quartile	Top quartile	Bottom quartile	Top quartile	Bottom quartile
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Base Period Gap (1982-1984)	60.83***	156.6***	123.0***	302.5***	0.417***	0.472***	20.76***	89.56***
	[5.786]	[13.50]	[7.946]	[23.16]	[0.0112]	[0.0202]	[1.143]	[3.292]
Increase in Gap, 2nd Pd. (85-90)	25.09***	52.54***	27.10***	50.66	-0.0549***	-0.0354	-0.867	-1.652
	[4.967]	[14.86]	[8.584]	[35.49]	[0.0139]	[0.0277]	[1.291]	[3.610]
Increase in Gap, 3rd Pd. (91-94)	31.50**	58.76**	42.51**	52.71*	-0.0102	0.00743	-1.85	-7.718
	[10.78]	[22.30]	[14.41]	[30.13]	[0.0159]	[0.0270]	[1.679]	[5.222]
Industry Output Growth Rate	0.575	-0.577	0.0623	16.89	-0.0391	-0.00813	1.155	4.714
	[1.110]	[7.038]	[1.632]	[18.78]	[0.0322]	[0.0212]	[1.019]	[4.555]
Observations	15,085	6,977	15,085	6,977	15,085	6,977	15,085	6,977
R-squared	0.726	0.824	0.606	0.762	0.506	0.571	0.498	0.651

Quit rate (defined as number of quits per 100 employees per month) is taken from Table 2 of Ragan (1984). All gaps are in thousands of 1979 pesos (deflator used is the CPI). Marginal product estimates are from a gross output Cobb-Douglas production function specification, which is estimated using Wooldridge (2009) modification of the Levinsohn-Petrin (2003) approach to address the simultaneous determination of inputs and productivity. See notes to Table 1 for definitions of input prices. Standard errors (reported in brackets) are clustered at the 4-digit industry level. * significant at 10%; ** significant at 5%; *** significant at 1%.