ESTIMATING LOST OUTPUT FROM ALLOCATIVE INEFFICIENCY, WITH AN APPLICATION TO CHILE AND FIRING COSTS

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Abstract—We propose a new measure of allocative efficiency based on unrealized increases in aggregate productivity growth. We show that the difference in 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 input’s use by one unit. We show how to estimate this gap using plant-level data for 1982 to 1994 from Chilean manufacturing. We find the gaps for blue- and white-collar labor are quite large in absolute value, and these gaps (unlike for materials and electricity) are increasing over time. The timing of the sharpest increases in the labor gaps suggests that they may be related to increases in severance pay.

I. Introduction

Many phenomena 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 nonoptimal 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 characterize allocative efficiency in terms of its impact on aggregate productivity growth (APG), defined as the change in aggregate final demand minus the change in aggregate expenditures on labor and capital. Under this definition of APG, Petrin and Levinsohn (2011) show that a unit increase in any input raises APG by that input’s concurrent value of marginal product-input cost gap. With common input costs across firms, aggregate output increases, holding aggregate 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 identify the net output change when a unit of labor, for example, is reallocated from one establishment to another or from being unemployed to being employed. We provide a framework for evaluating policy changes that affect these plant-level gaps, such as increases in firing or hiring costs.

Our approach can readily be carried out in standard programming packages. Our estimates for the value of marginal products use estimates from production functions, which have a wide variety of estimators.1 Production data also typically contain measurements on input expenditures, and we use these to approximate the marginal cost of each input.

Our approach to measuring allocative inefficiency is closest in spirit to Hsieh and Klenow (2009) and is also related to the wide collection of definitions of reallocation from Basu and Fernald (2002) and from Baily, Hulten, and Campbell (BHC, 1992) and its derivatives (Olley & Pakes, 1996, and Foster, Haltiwanger, & Krizan 2001). The main difference between our definition of reallocation and all of these variants is that they are not based on definitions of APG that equal the change in final demand minus the change in expenditures on labor and capital. This weakens their link to the theory literature on reallocation and growth (see Aghion & Howitt, 1992, or Caballero & Hammour, 1996, and the large literature that has followed). A second important difference with some of these alternative approaches is that we avoid the use of cost shares to estimate production function parameters or markups because the theory that motivates doing so does not hold when the cost function is not differentiable, as in any s-S type setting like a world with adjustment costs for labor or capital.2

We illustrate our approach using plant-level data from 1982 to 1994 in Chile, one of Latin America’s fastest-growing countries in the late 1980s and 1990s. 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 period 1982 to 1994. We find negligible gaps for materials across estimators and small gaps for electricity inputs but large gaps for blue- and white-collar labor inputs. On average, the gaps for labor equal approximately one year’s salary 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 aggregate value added of 0.5%.3

1 Our Stata code, which is available at our Web sites, contains three different estimation approaches for production functions and illustrates how to construct estimates of the gaps from them.
2 See Bentolila and Bertola (1990), who provide evidence of nondifferentiable adjustment costs for labor, and also Caballero and Engel (1993, 1999), who provide similar evidence for capital. See also the discussion in Bond and Van Reenen (2007).

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We then look for an impact on allocative efficiency of two increases in the cost of dismissing workers. 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 eleven 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 affect plant-level gaps, and we 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 affect adjustment costs for inputs like labor or capital affect only 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 in the spirit of a difference-in-differences approach to identification.

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 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 suggest that at least part of the decrease in allocative efficiency may have occurred because of the increase in firing costs.

We undertake a series of checks to test the robustness of our results. In particular, we examine robustness to (a) using two alternative production functions, (b) using an alternative definition of the productivity residual, (c) using two tests to address potential measurement error in wages, (d) using a sample-split test based on excess turnover rates (to see if industries with greater voluntary turnover are less affected by increases in job security), (e) differences in industry unionization rates (to control for changes in bargaining environment that would likely affect unionized industry more strongly), (f) using an alternative deflator for nominal gaps, and (g) exclusion of entrants and exits. Our main findings are robust to all of these checks. We also check and find that the gaps are correlated with probability of exit.

The paper proceeds as follows. Sections II to IV develop the reallocation framework and estimation methodology. Section V summarizes the key economic reforms in Chile over the period that we examine (1982–1994). Section VI describes the plant-level data. Section VII provide details of estimation, and section VIII presents the baseline results and robustness checks. Section IX concludes.

II. Measuring Lost Output Due to Allocative Inefficiency

We use the accounting framework from Petrin and Levinsohn (2012) to derive aggregate productivity growth from the microlevel and derive the reallocation terms. (Readers not interested in the details can skip to section IIA, and then go directly to implementation in section IV.)

We assume there are at most $N$ plants in the economy, each of which produces one good. Each plant $i$’s production technology is given by

$$Q^i(X_i, M_i, \omega_i),$$

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 $\omega_i$ 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

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

where $\sum_j M_{ji}$ 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 differential for $i$’s final demand is given as $dY_i = dQ_i - \sum_j dM_{ji}$. 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:

$$APG \equiv \sum_i P_i dY_i - \sum_i \sum_k W_{ik} dX_{ik},$$

where any of the $N$ products may potentially be used as an input in production. The setup extends to multiproduct plants.
where $W_{ik}$ equals the unit cost to $i$ of the $k$th 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  
\[
\sum_i \sum_k \left( P_i \frac{\partial Q_i}{\partial X_k} - W_{ik} \right) dX_{ik} + \sum_i \sum_j \left( P_i \frac{\partial Q_i}{\partial M_j} - P_j \right) dM_{ij} - \sum_i P_idFi + \sum_i P_i \frac{\partial Q_i}{\partial d\omega_i},
\tag{3}
\]

where $\frac{\partial Q_i}{\partial X_k}$ and $\frac{\partial Q_i}{\partial M_j}$ are the partial derivatives of the output production function with respect to the $k$th primary input and the $j$th 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; $\frac{\partial Q_i}{\partial d\omega_i}$ 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 $i$.  

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 approximation to the potential efficiency gains to the economy from moving one step in the direction of being more efficient. Equation (6) is partial equilibrium in nature and assumes the economy is not constrained in a way that makes this labor reallocation impossible.

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 $t \in [0, 1]$ (see note 6).

We use the reallocation terms to define the change in aggregate productivity growth due to changes in allocative efficiency:
\[
\Delta AE \equiv \int_0^1 \sum_i \sum_k \left( P_i \frac{\partial Q_i}{\partial X_k} - W_{ik} \right) dX_{ki} + \int_0^1 \sum_i \sum_j \left( P_i \frac{\partial Q_i}{\partial M_j} - P_j \right) dM_{ij}.
\tag{7}
\]

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 positive gap 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, a tax on wages, or a markup charged by the firm. Eliminating the entire gap

\[\text{Lemma 1.} \quad \text{The average absolute gap across firms between labor’s value of marginal product and wage equals the average productivity gain from adjusting labor by one unit in the optimal direction at every firm, holding all else constant.} \]

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\[\text{This gap could be due to any type of friction, including firing costs, a tax on wages, or a markup charged by the firm. Eliminating the entire gap} \]
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.

III. Input Demand with Adjustment Costs

We illustrate how market power and adjustment costs affect the allocative efficiency measure given in equation (7) using a simple dynamic model of input demand based on Bentolila and Bertola (1990). The production function is given as $Q(o_t, L_t)$ and is assumed differentiable, increasing, and concave in labor $L_t$ (the one input), and with demand or productivity shock $o_t$. $o_t$ is stochastic so the firm is uncertain about future demand or 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

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

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 $P(Q_t)$. The firm then chooses an employment policy that maximizes the expected present value of profits over the future:

$$V_t \equiv \max_{L_t} \mathbb{E}_t \left[ \int_t^\infty e^{-\tau} \left( (P(Q_{\tau})Q(o_{\tau}, L_{\tau}) - W_t L_{\tau})d\tau - C(dL_{\tau}) \right) \right].$$  

Assuming the marginal revenue product of labor is well defined, we have

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

where $\varepsilon \equiv \frac{P}{Q} \left(\frac{\partial Q}{\partial P} \right)$ 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:

$$E_t \left[ \int_t^\infty (MRP_t^l - W_t)e^{-(\tau-t)}d\tau \right] = -F$$  

if $dL_t < 0$,  \hspace{1cm} (9)

$$-F < E_t \left[ \int_t^\infty (MRP_t^l - W_t)e^{-(\tau-t)}d\tau \right] < H$$  

if $dL_t = 0$,  \hspace{1cm} (10)

$$E_t \left[ \int_t^\infty (MRP_t^l - W_t)e^{-(\tau-t)}d\tau \right] = H$$  

if $dL_t > 0$.  \hspace{1cm} (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. Instead, when firing, the firm chooses labor such that the discounted expected $MRP_t^l$ 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 $MRP_t^l$ to the discounted cost of wages plus today’s hiring cost. There is also a range of realized values for $o_t$ such that the firm does not adjust, in which case the difference between the discounted expected $MRP_t^l$ and the discounted wage falls within the range $[-F, H]$. Note that equations (9) to (11) make it clear that definitions of reallocation based on the use of cost shares are not consistent in the face of these types of adjustment costs, as the first-order conditions from cost minimization no longer imply that cost shares are equal to production function parameters (or markups times these parameters).

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 equation (7) improves as the economy moves from a setting where firms use the decision rules from equation (9) to (11) to the setting where firms choose labor equating $MRP_t^l = W$ in every period.

A. The Information in “Freely Adjustable” Input Gaps

Inputs without adjustment costs will have $MRP_t^l$ 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 two-input
production function that involves labor and another “freely adjustable” input $M$, with a unit price of $P^m$.

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

The new value function in equation (8) becomes

$$V_t \equiv \max_{L_t,M_t} \left[ \int_t^{\infty} e^{-r(t-s)} \left\{ (P(Q)Q(L_t,M_t,\omega_t)$$

$$- WL_t - P^m_t M_t) d\tau - C(dL_t) \right\} \right].$$

(12)

Lemma 2 gives the decision rule for $M$:

**Lemma 2.** Assume $P(\cdot)$ and $Q(\cdot)$ are differentiable and $C(dM) = 0$. 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.** Equation (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 $M$ for all $t$.

Optimization for labor choice yields the same conditions as in equations (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 that the marginal revenue product of any freely adjustable input 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; 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, for example, increase with a change in the competitive environment that affects markups or taxes on output.

**IV. The Gap Methodology**

In this section we provide an overview of how VMP and MRP gaps can be estimated using plant-level data.

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

$$q_{it} = \beta_s p_{it}^{\mu_s} + \beta_u p_{it}^{\mu_u} + \beta_k k_{it} + \beta_m m_{it} + \beta_v v_{it} + \beta_e e_{it} + \beta_v v_{it} + \varepsilon_{it},$$

(13)

where $q_{it}$ is the log of the real output, $m_{it}$ is log of real value of intermediate materials, $p_{it}^{\mu_s}$ is the log of the number of skilled (white-collar) employees, $p_{it}^{\mu_u}$ is the log of the number of unskilled (blue-collar) employees, $k_{it}$ is the log of the real capital stock employed, $e_{it}$ is the log of electricity purchased (quantity), and $v_{it}$ is the log of the services used by firm $i$ in year $t$. The productivity shock is given as

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

with $\omega_{it}$ representing a transmitted component and $\eta_{it}$ representing an i.i.d. (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, for example, by

$$\frac{\partial Q_{it}^s}{\partial \beta_s} = \beta_s e^{\mu_s} (L_{it}^1)^{\beta_s-1} (L_{it}^u)^{\beta_u} (K_{it})^{\beta_k} (M_{it})^{\beta_m} (V_{it})^{\beta_v} (E_{it})^{\beta_e}.$$

(14)

where the capitalized variables are levels of the logged variables defined above. 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 $G_{it}^m$ and electricity $G_{it}^e$ are given by

$$G_{it}^s = |VMP_{it}^s - w_{it}^u|,$$

$$G_{it}^u = |VMP_{it}^u - w_{it}^u|,$$

$$G_{it}^m = |VMP_{it}^m - p_{it}^m|,$$

$$G_{it}^e = |VMP_{it}^e - P_{it}^e|,$$

where $w_{it}^u$ and $w_{it}^s$ denote the wage rate for unskilled (blue-collar) and skilled (white-collar) labor, respectively, $P_{it}^m$ is the price for materials, and $P_{it}^e$ is the price for electricity. These gaps are in nominal terms, so we deflate using the consumer price index, giving

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

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 $P_{it} = A_{it} Q_{it}^{1/n}$, and a production...
function as in equation (13), the parameters of the revenue function have form $\beta'_j = \beta_j (1 + \frac{1}{\varepsilon})$:

$$r_{it} = \beta'_{s} y_{sit} + \beta'_{m} k_{it} + \beta'_{m} m_{it} + \beta'_{v} v_{it} + \beta'_{e} e_{it} + \varepsilon'_{it}.$$ (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 CPI to improve comparability over time).

V. The Chilean Job Security Reforms

Firing costs are pervasive around the world (see figure 2, which is taken from Heckman & Pagés, 2004). Theoretically it is an open question as to whether they have any impact on economic efficiency as market participants may be able to undo the distortion.10 In Chile, workers have traditionally been provided with job security through three means: advance notices for dismissal, limitations on the use of fixed-term labor contracts, and severance payments on dismissal.11 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 who 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,” defined in the Immobility Law of 1966, 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 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.12

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

\[ C_t = \sum_{s=1}^{7} \beta^{s-1} \delta (1 - \delta) \times \left( b + a_s S_t^{f_s} + (1 - a_s) S_t^{u_s} \right), \]

with \( \beta \) denoting the discount factor, \( \delta \) the probability of retention, \( b \) the cost of advance notice, \( a_t \) the probability that economic difficulties of the firm are considered just, \( S_t^{f_s} \) the payment under justified cause, and \( S_t^{u_s} \) the payment under unjustified dismissal. \( \delta (1 - \delta) \times (1 - \delta) \) then equals the probability of firing at year \( s \), and \( (b + a_s S_t^{f_s} + (1 - a_s) S_t^{u_s}) \) is the expected cost associated with firing at that time.13

Figure 3, which is calculated using their best estimates for a firm in Chile, 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- to 14-month range of Colombia, Brazil, Peru, and Ecuador (see figure 2).15

VI. The Data and Variables

A. Data

We use the annual Chilean Manufacturing Census (Encuesta Nacional Industrial Anual) conducted by the Chilean government statistical office (Instituto Nacional de Estadística). The survey covers all manufacturing plants in Chile with more than ten employees and has been conducted annually since 1979. There are about 5,000 firms every year, with an entry rate and an exit rate of about 5% 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 online Appendix figure A.3).

This survey has been used in a number of previous studies.16 The survey provides an industry indicator and measures of

12 The term just firings or dismissals is based on the phrasing of the Chilean labor law and taken from Edwards and Edwards (2000). The equivalent terminology in U.K. labor law and other contexts is “fair dismissals.”

13 A more comprehensive approach would have indices for both the firm and the worker, \( C_{t,i} \), although this calculation would require matched employer-employee data.

14 They assume \( \beta \) equal to 0.92, \( \delta \) equal to 0.88, \( b \) equal to 1, \( a_t \) starting at 0.8, falling to 0 from 1985 to 1990, and then increasing in 1991 to 0.9, \( S_t^{f_s} \) at 0 until 1990 when it increases to one month’s pay for every year worked up to eleven months’ maximum, and \( S_t^{u_s} \) at one month’s pay for every year worked up to five months’ maximum, for 1981 to 1990, and then increasing to 1.2 months’ pay for every year worked up to a maximum of eleven months.

15 A number of other political and economic changes took 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 postrecession period.

16 See Levinsohn and Petrin (2003) and citations therein.
of output, inputs, wages, employment, and investment. A detailed description of how the longitudinal samples were combined into a panel from 1979 to 1986 can be found in Liu (1991). We extended this to 1994 following broadly the procedure used by Liu. Further, we supplemented the raw data with three-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 data from Edwards and Edwards (1991, 2000).\(^{17}\)

### B. Output, Input, Price Measures, and Capital

Plant-level real output is total revenue deflated with a threedigit 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 has its own three-digit price deflator. Over 30,000 plant-year observations report 0 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.\(^{19}\) Data on book value of capital are available for the years 1980–1981 and 1992–1994. 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 to 1991. For other firms, we build capital series backward and forward using the data on book value available for 1992 to 1994. 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.

### C. 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.

We examine general trends in the average real wage rates in online 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.

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.\(^{20}\) For plants that fire workers, this causes the estimated average wage to be higher than the marginal wage. For blue-collar workers, 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 & Sivadasan, 2006), an observed average fraction of workers fired giving a firing spell of 17.9% (from table 7 of Petrin and Sivadasan, 2006), and an average tenure of five years for workers, which leads to a 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%, which is small relative to the size of the gap and the change in the gaps over time that we report in section VIII. We also note that we find approximately 62% of the estimated gaps for both blue- and white-collar labor are positive, and for these plants, the error works to reduce the magnitude of the estimated gap relative to its true size. We undertake further tests addressing the potential impact of wage mismeasurement in section VIII but find no evidence that this mismeasurement could explain either the size of the gaps or their change over time.

### VII. Estimation

There are some important issues that researchers 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. In the baseline analysis, we employ the approach proposed by Wooldridge (2009) that synthesizes ideas to address the simultaneity problem from Levinsohn and Petrin (LP, 2003) and Olley and Pakes (OP, 1996), while also addressing the critique of these approaches by Ackerberg, Caves, and Fraser (2006). We use the proxy variable materials proposed by LP instead of the investment proxy proposed by OP because of the lumpiness of investment in our plant-level data. We estimate the production function separately by three-digit industry to allow these parameters to vary by industry. Also, given that the job security reforms introduce adjustment costs

\(^{17}\) We thank Andrés Hernando for providing us with some of these deflators.

\(^{18}\) Results are robust to dropping these observations.

\(^{19}\) This is described in detail in online Appendix D.

\(^{20}\) Alejandra Cox-Edwards advised us on this point. Our results are robust to using only wages and bonus.
to labor inputs, we treat blue- and white-collar labor as state variables (in addition to capital) in the estimation.21

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 predominant approach in the literature and use the former.

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 IV, for skilled labor when we use the entire error in the estimation of the marginal product, we get

\[
\beta_s \left( \frac{P_n Q_n}{P_{ht}} \right) \left( \frac{1}{L_s} \right),
\]

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 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.

VIII. The Gap Results for Chile, 1982–1994

A. Baseline Results

Over the entire sample period, we observe 43,675 gaps for blue-collar labor, with 9,558 observations in the three-year period prior to the first reform (1982, 1983, and 1984), 18,852 observations in the period between the two reforms (from 1985 to 1990), and 15,265 observations in the four-year period after the second reform (from 1991 to 1994). Before conditioning on plant-specific differences and other observed control variables, we analyze the unconditional means and medians of the gap distribution.

The average (median) unconditional gaps for blue-collar labor in real terms across the three periods are 79,000 (33,000), 107,000 (35,000), and 112,000 (41,000) pesos.22 The average (median) unconditional gaps for white-collar labor across periods are 124,000 (69,000), 155,000 (83,000), and 173,000 (95,000) pesos. These compare to average wages in our data of 77,000 pesos a year for blue-collar workers and 158,000 pesos a year for white-collar workers. Thus, the average gaps are close to or more than a year’s wage for both types of workers. The gaps are also growing over time for both types of laborers.

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 to 1990 and one for 1991 to 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 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 84,000 pesos per year, and for white-collar labor it was 139,000 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 23,000 pesos and 18,000 pesos, respectively. In the third period, the blue-collar gap increases slightly (by about 2,000 pesos), while the white-collar gap increases further, by almost 6,000 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.23 For the base period, a one-step move of blue-collar labor in the “right” direction leads to almost a 0.5% increase in aggregate 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

21 Appendix C has more detail on the estimation approach as well as a discussion of estimates and overidentification tests. Programs are available in a programming appendix at http://webuser.bus.umich.edu/jagadees/other/chile_code.htm.

22 All results are reported in real 1979 Chilean pesos.

23 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 (we winsorize the observations by 2.5% on both tails).
The timing of the results is consistent with the timing of the job security changes. The labor gaps are fairly level for white-collar employees in the prechange period until 1985, when they increase in 1986–1987 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 1986–1987. 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).

By lemma 2, we know that if changes in markups or output taxes, for example, are the cause for the increased gap between labor VMP and wages that we see in table 1, then we should see this change drive a gap between MRP and input prices for all inputs. In table 2 we report estimates of the marginal revenue product gaps for materials and electricity. Examining the VMP results in columns 5 to 8 of table 1 for materials and electricity, 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 to 1990 and 1991 on. Thus, whatever the reason for the increase in gaps for labor input, the results suggest it is not a friction that affects all inputs.

We compare the year-to-year timing of the changes in gaps across inputs. Figure 5 plots the coefficients on the inputs that do not contain the line are significantly different from the 1984 level. All nine of the blue-collar increases in job security (though this increase is smaller than the jump in 1986).

## Table 1

<table>
<thead>
<tr>
<th></th>
<th>Blue Collar</th>
<th>White Collar</th>
<th>Materials</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base period gap (1982–1984)</td>
<td>83.42***</td>
<td>83.77***</td>
<td>138.6***</td>
<td>138.9***</td>
</tr>
<tr>
<td></td>
<td>[6.620]</td>
<td>[6.622]</td>
<td>[5.488]</td>
<td>[5.435]</td>
</tr>
<tr>
<td>Increase in gap, second period (1985–1990)</td>
<td>23.47***</td>
<td>22.99**</td>
<td>17.98**</td>
<td>17.56**</td>
</tr>
<tr>
<td></td>
<td>[8.713]</td>
<td>[8.682]</td>
<td>[7.387]</td>
<td>[7.257]</td>
</tr>
<tr>
<td></td>
<td>[9.038]</td>
<td>[9.066]</td>
<td>[7.922]</td>
<td>[7.916]</td>
</tr>
<tr>
<td>Industry output growth rate</td>
<td>2.201</td>
<td>1.93</td>
<td>1.93</td>
<td>1.93</td>
</tr>
<tr>
<td></td>
<td>[1.904]</td>
<td>[2.076]</td>
<td>[2.076]</td>
<td>[2.076]</td>
</tr>
<tr>
<td>Observations</td>
<td>43,675</td>
<td>43,675</td>
<td>43,675</td>
<td>43,675</td>
</tr>
</tbody>
</table>

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 the Wooldridge (2009) modification of the Levinsohn and 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 three-digit industry-specific price index. Electricity prices are derived from establishment-specific quantity and value information. We estimate production functions separately for each three-digit industry. Standard errors (reported in brackets) are clustered at the four-digit industry level.

> **Table 1.** 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

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By lemma 2, we know that if changes in markups or output taxes, for example, are the cause for the increased gap between labor VMP and wages that we see in table 1, then we should see this change drive a gap between MRP and input prices for all inputs. In table 2 we report estimates of the marginal revenue product gaps for materials and electricity. Examining the VMP results in columns 5 to 8 of table 1 for materials and electricity, 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 to 1990 and 1991 on. Thus, whatever the reason for the increase in gaps for labor input, the results suggest it is not a friction that affects all inputs.

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.

B. Robustness Checks

In this section we examine robustness to (a) alternative production function specifications, (b) an alternative definition of the productivity residual, (c) measurement error in wages, (d) differences in excess worker turnover, (e) differences in industry unionization rates, (f) use of an alternative deflator for nominal gaps, and (g) exclusion of entrants and exiters. Our main findings are robust to all of these checks. We also show that gaps are correlated with probability of exit.

Alternative production function specifications. We use the same specification as in equation (13) but estimate it using plant-level fixed effects that vary by the three time periods. This estimator is consistent if \( \omega_{it} = \omega_{ip} \), where \( p \) stands for one of the three time periods (period 1 is 1982 to 1984, period 2 is 1985 to 1990, and period 3 is 1991 to 1994). 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.

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 elastic-
ity of substitution between inputs is restricted to be 1. As an
alternative, we consider the following second-order translog
specification,

\[ q_{it} = \sum_j \beta_j X_{it}^j + \sum_j \sum_k \beta_{jk} X_{it}^j X_{it}^k + e_{it}, \]  

(16)

where \( i \) indexes plants, \( t \) indexes years, and \( j \) and \( k \) index
the different inputs. We estimate the translog production function
using the same fixed effects. The gap results using the translog
production function are presented in columns 5 to 8 of table 3.

Again we find broadly the same patterns as in the base case
in table 1 for both the labor inputs and control inputs.

**Using the transmitted component of productivity.** In this
section, we check the robustness of the results to condition-
ing on only the transmitted component of productivity. As
discussed in section IV, if \( \eta_{it} \) arises essentially from measure-
ment error in output, then this term should be eliminated
from the productivity residual when estimating the marginal
product. In order to eliminate \( \eta_{it} \), we form an estimator
using Wooldridge (2009) modification of the Levinsohn and Petrin
(2003) approach to address the simultaneous determination
of inputs and productivity. To calculate the marginal product,

\[ \text{Marginal Product} = \frac{\partial q_{it}}{\partial X_{it}} = \sum_j \beta_j X_{it}^j + \sum_j \sum_k \beta_{jk} X_{it}^j X_{it}^k, \]  

(17)

where we estimate \( \sum_j \beta_j X_{it}^j \) from a fixed effect
translog production function, then we subtract the contribution
of the inputs using

\[ \hat{\eta}_{it} = \hat{\beta}_{0} + \hat{\beta}_{1} X_{it}^1 + \hat{\beta}_{2} X_{it}^2 + \ldots + \hat{\beta}_{k} X_{it}^k + \hat{\beta}_{m} m_{it} + \hat{\beta}_{e} e_{it} + \hat{\beta}_{v} v_{it}. \]  

The results are presented in table 4. These are qualitatively
similar to that in baseline case in table 1.

**Table 3.**—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

<table>
<thead>
<tr>
<th></th>
<th>Cobb-Douglas Fixed Effects</th>
<th>Translog (Order 2) Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blue Collar</td>
<td>White Collar</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Base period gap (1982–1984)</td>
<td>111.2***</td>
<td>162.9***</td>
</tr>
<tr>
<td></td>
<td>[8.618]</td>
<td>[5.579]</td>
</tr>
<tr>
<td>Increase in gap, second period (1985–1990)</td>
<td>36.88***</td>
<td>52.62***</td>
</tr>
<tr>
<td></td>
<td>[10.56]</td>
<td>[6.667]</td>
</tr>
<tr>
<td>Increase in gap, third period (1991–1994)</td>
<td>33.60***</td>
<td>56.32***</td>
</tr>
<tr>
<td></td>
<td>[12.45]</td>
<td>[8.873]</td>
</tr>
<tr>
<td>Industry output growth rate</td>
<td>9.43</td>
<td>11.67</td>
</tr>
<tr>
<td></td>
<td>[5.690]</td>
<td>[7.810]</td>
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<tr>
<td>Observations</td>
<td>41.067</td>
<td>41.067</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.801</td>
<td>0.655</td>
</tr>
</tbody>
</table>

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 three-digit industry. See notes to table 1 for definitions of input prices. Standard errors (reported in brackets) are clustered at the four-digit industry level. Significant at *10%, **5%, ***1%.
Measurement error in wages. In section VI C, we showed that a simple estimate of the amount of error introduced into the gap estimate and its change by the inability to separate severance pay from the wage bill is small. Here we further explore the issue by noting that the measurement error does not arise for plants that do not fire workers. Thus, the average industry wage rate in plants that increased employment may not arise for plants that do not fire workers. Thus, the average of wages.

In period $t$, where $\Delta L_{ijt}$ is the difference-in-difference-in-differences. Combining this with the expectation that mandated changes in firing costs, we expect these increases to be lower in industries that have higher voluntary worker turnover rates. Combining this with the expectation that mandated severance payments should have no effect on the gaps for the freely adjustable inputs, we get a test in the spirit of difference-in-difference-in-differences.

We proxy for the extent of Chilean industry-level voluntary turnover using U.S. excess worker turnover (defined as worker turnover less job turnover). Data on job and worker turnover are obtained from the quarterly workforce indicator (QWI) database, which is based on data from the LEHD. We collected data by three-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 three-digit code and the ISIC three-digit code.

We then split out the sample into two groups. One group contains estimated gaps from plants in industries with excess turnover above the median, and the second group contains the plants in industries below the median. In table 6, we find that the increases in gaps for blue-collar and white-collar worker (in columns 1 and 2) are bigger in magnitude for plants below

Table 5.—Gap between the Value Marginal Product and the Input Price, 1982–1994: Robustness to Using Alternative Wage Measure and Positive Gaps Only

<table>
<thead>
<tr>
<th></th>
<th>Blue Collar</th>
<th>White Collar</th>
<th>Positive Gaps Only</th>
<th>Blue Collar</th>
<th>White Collar</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) (2)</td>
<td>(3) (4)</td>
<td>(5) (6)</td>
<td>(7) (8)</td>
<td>(9) (10)</td>
<td>(11) (12)</td>
</tr>
<tr>
<td>Base period gap</td>
<td>100.8***</td>
<td>100.2***</td>
<td>196.0***</td>
<td>199.6***</td>
<td>109.1***</td>
</tr>
<tr>
<td></td>
<td>[4.577]</td>
<td>[3.928]</td>
<td>[9.992]</td>
<td>[11.911]</td>
<td>[6.682]</td>
</tr>
<tr>
<td>Increase in gap,</td>
<td>16.23**</td>
<td>17.02**</td>
<td>7.737</td>
<td>2.500</td>
<td>44.79***</td>
</tr>
<tr>
<td>second period</td>
<td>[6.556]</td>
<td>[5.599]</td>
<td>[15.73]</td>
<td>[18.76]</td>
<td>[6.962]</td>
</tr>
<tr>
<td>Increase in gap,</td>
<td>37.46***</td>
<td>38.17***</td>
<td>55.37***</td>
<td>50.62***</td>
<td>44.24***</td>
</tr>
<tr>
<td>1994)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry output</td>
<td>−4.04</td>
<td>24.75</td>
<td>19.52***</td>
<td>4.494</td>
<td></td>
</tr>
<tr>
<td>growth rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[11.68]</td>
<td>[22.85]</td>
<td>[7.137]</td>
<td>[3.625]</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>43,346</td>
<td>43,346</td>
<td>43,502</td>
<td>43,502</td>
<td>26,949</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.736</td>
<td>0.736</td>
<td>0.525</td>
<td>0.525</td>
<td>0.803</td>
</tr>
</tbody>
</table>

All gaps are in thousands of 1979 pesos (deflator used is the CPI). In columns 1 to 4, we use as an alternative an industry-level wage measure based on the changes in employment and wage bill at firms increasing employment by at least 10%. In columns 5 to 8, we use only observations that have positive gaps; for these cases, measurement error in wages biases the gap downward. Marginal product estimates are from a gross output (revenue deflated by industry-specific deflators) Cobb-Douglas production function specification, which is estimated using the Wooldridge (2009) modification of the Levinsohn and 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 three-digit industry-specific price index. Electricity prices are derived from establishment-specific quantity and value information. We estimate production functions separately for each three-digit industry. Standard errors (reported in brackets) are clustered at the four-digit industry level. Significant at *10%, **5%, ***1%.

We also look at how the gaps change for just the plants that have positive gaps. As we noted in section VI C, the upward bias in measured wages for firms that fire workers leads to a downward bias on measured absolute gaps for observations with positive gaps. The results from examining this subsample are presented in table 5 (columns 5–8). We continue to find significant increases in both blue- and white-collar gaps in the periods after the passage of the laws relative to the period before the laws.

Conditioning on excess worker turnover. In industries that have relatively high voluntary worker turnover, managers should have more flexibility to adjust employment levels down without firing workers. If the increases in the gap for blue- and white-collar labor 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. Combining this with the expectation that mandated severance payments should have no effect on the gaps for the freely adjustable inputs, we get a test in the spirit of difference-in-difference-in-differences.

We proxy for the extent of Chilean industry-level voluntary turnover using U.S. excess worker turnover (defined as worker turnover less job turnover). Data on job and worker turnover are obtained from the quarterly workforce indicator (QWI) database, which is based on data from the LEHD. We collected data by three-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 three-digit code and the ISIC three-digit code. We then split out the sample into two groups. One group contains estimated gaps from plants in industries with excess turnover above the median, and the second group contains the plants in industries below the median. In table 6, we find that the increases in gaps for blue-collar and white-collar worker (in columns 1 and 2) are bigger in magnitude for plants below

...
The data for 2009 include information on the labor histories for each respondent (going back to 2006). For each historical employment spell, the respondents industry of employment (four-digit ISIC) as well as union membership status is tracked. We define a unionization rate at the three-digit industry level as the fraction of observations for the industry where the respondent reported belonging to the union. The results from examining samples split based on industry unionization rates are presented in online Appendix Table A.4. We find that the increase in average absolute gaps for white- and blue-collar labor is as big, if not bigger, in industries below the median in terms of unionization rates. Again, there is no systematic pattern of increase in either sets of industries for the control inputs.

Robustness to using an alternative deflator. In the baseline analysis, we deflate the nominal gaps with the CPI to denote all gaps in 1979 pesos. The results from using the GDP deflator are presented in online Appendix Table A.5 and are very similar to using the CPI deflator.

Robustness to entry and exit. Because we use plant-level fixed effects in the gaps regressions, the changes in gaps for period 2 (1985–1990) and period 3 (1991–1994) are identified off plants that exist in at least two of the three time periods. We investigate whether changes in composition from new entrants in period 2 that carry over to period 3 or plants that survived from period 1 to 2 but exit in period 2 affect the results. In columns 1 to 4 of online Appendix Table A.6, we restrict observations to plants that existed in at least two of the three years (1982–1984), all six years of period 2 (1985–1990), and at least two of the four years of period

25 Results were qualitatively robust to using the OLS fixed effects production function (available on request).
26 Landerretche, Lillo, and Puentes (2011) use this survey to study the effect of unionizations on wages. The data were generously provided to us by the Microdata Center at the University of Chile. In particular, we thank Esteban Puentes for facilitating access to the data and helping us with data-related questions.

27 Spells corresponding to inactivity or cessation from the labor market are excluded. Also, three-digit industries for which we had fewer than twenty observations were excluded; this led to the exclusion of only four smaller three-digit industries that constituted about 5% of the data we used in the baseline analysis.

28 Results were qualitatively robust to using the OLS fixed-effects production function (available on request).
3 (1991–1994). In columns 5 to 8, we use a less restrictive condition, retaining plants that existed in at least two years in each of the three time periods. The results are qualitatively very similar to the baseline results.

The checks in columns 1 to 4 also address a concern arising from limitations in the measurement of capital stock. As discussed in online Appendix D, for plants that exit the sample for short durations, we assume that the investment is 0 in the missing years. This may lead to systematic mismeasurement of capital series (as any mismeasurement in investment gets propagated when using the perpetual inventory method to build the capital series). Because the mismeasurement due to missing data is not a concern for the sample in columns 1 to 4, the robustness of the baseline results in this sample is reassuring.

**Correlation between gap and exit hazard or propensity.** We explore whether plants with larger absolute gaps are more likely to exit using an exponential hazard model, as well as a linear probability model. We control for size and age in both setups. Industry-year fixed effects are included in the linear model, and industry and year dummies are controlled for separately in the hazard models (where including a large number of fixed effects is computationally cumbersome). The results are presented in online Appendix table A.7. We find that larger blue-collar gaps are indeed significantly associated with higher exit hazard and propensity (column 1 and column 3). We find that the result holds for both positive and negative blue-collar gaps separately (columns 2 and 4). Similarly, we find in columns 5 and 6 that the white-collar gaps are associated with higher exit hazard, but this effect is not statistically significant except in the case of negative gaps. The effects are significant in the linear exit propensity models (where all effects are statistically significant).

**IX. Conclusion 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.

Our approach is simple and transparent, and it can be carried out readily in standard programming packages on aggregate data or the large micro data sets 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. In the context of assessing the impact of policy changes that affect adjustment costs for particular inputs, we show how gaps for other inputs can serve as controls to rule out changes from frictions such as output taxes and subsidies or nonoptimal managerial behavior that would be expected to affect the gaps for all inputs.

We use the VMP-input price gap to examine overall allocative inefficiency in Chile. We also focus on the effects of two mandated increases in the costs of dismissing employees. 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. The interpretation of the results is subject to the caveat that the data available for Chile are imperfect, as discussed and addressed to the extent possible in section VIII B of the paper.

We see the main contribution of the paper as proposing a simple and novel methodology to estimate allocative inefficiency. 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 the cost of production are diverging from one another.

**References**


