

Factor Adjustments after Deregulation: Panel Evidence from Colombian Plants

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November 2006

Abstract

In this paper, we analyze employment and capital adjustments using a panel of plants from Colombia. We allow for non-linear adjustment of employment to reflect not only adjustment costs of labor but also adjustment costs of capital, and vice-versa. Using data from the Annual Manufacturing Survey, which include plant-level prices, we generate measures of plant-level productivity, demand shocks, and cost shocks, and use them to measure desired factor levels. We then estimate adjustment functions for capital and labor as a function of the gap between desired and actual factor levels. As in other countries, we find non-linear adjustments in employment and capital in response to market fundamentals. In addition, we find that employment and capital adjustments reinforce each other, in that capital shortages reduce hiring and labor shortages reduce investment. Moreover, we find that the market-oriented reforms introduced in Colombia after 1990 increased employment adjustments, especially on the job destruction margin, as well as investments, but reduced capital deployments. Finally, we find that while completely eliminating frictions from factor adjustments would yield a dramatic increase in aggregate productivity through

We thank Andres Fernández and Pablo Medina for excellent research assistance, Departamento Administrativo Nacional de Estadística and administrators of the Annual Manufacturing Survey for data access and for answering our queries on methodological issues. We thank presentation participants at the Centre for Economic Performance/Institute for Fiscal Studies Productivity and Innovation Seminar, Columbia Development Seminar, Exeter Economics Seminar, the IFS seminar, an NBER Productivity Meeting and the Yale Trade and Development Seminar, and especially Orazio Attanasio, Eli Berman, Nick Bloom, Ken Chay, Penny Goldberg, Rachel Griffith, Dan Hamermesh, Norman Loayza, Steve Pischke, Luis Servén, Chad Syverson and John Van Reenen for very useful comments. Research support was provided by the World Bank, the Tinker Foundation, and a GEAR grant from the University of Houston.

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improved allocative efficiency, the reforms impact on factor adjustment generated only modest improvements on allocative efficiency. At the same time, allocative efficiency increased substantially following the reforms suggesting that reforms must have worked through other channels to eliminate barriers to allocative efficiency.

Keywords: Joint factor adjustment, irreversibilities, adjustment costs, input reallocation, deregulation.

JEL Codes: E22, E24, O11, C14, J63.

1 Introduction

Well-functioning market economies require that producers be able to change their input mix in response to shocks. Yet, for the main factors of production, namely capital and labor, there is limited scope for continual adjustment. There is evidence that, at the level of production units, changes in investment and employment are associated with substantial restructuring rather than frequent tinkering. Lumpy adjustment of both capital and labor at the plant-level is a stylized fact in studies for the U.S. and other countries (e.g., Caballero, Engel and Haltiwanger (1995, 1997), Cooper, Haltiwanger and Power (1999), Doms and Dunne (1998), Gelos and Isgut (2001), Gourio and Kashyap (2006), and Nilsen and Schiantarelli (2003)). One explanation of these findings is that fixed adjustment costs and irreversibilities make changes in factor demands less frequent and more substantial. However, lumpy adjustments have mainly been studied in the context of individual adjustment margins, either capital or labor. Although a few studies have analyzed joint adjustments of capital and labor, most examine this interaction using sectoral level data and convex adjustment cost models (Nadiri and Rosen (1969), Shapiro (1986), Rossana (1990), and Hall (2004)).¹

In this paper, we study the joint evolution of employment growth and investment using panel data for Colombian manufacturing plants. In contrast to most previous studies using micro data, our framework analyzes nonlinear adjustment allowing for interactions between the capital and labor margins. Factor demands may be inter-related so that frictions for one factor may generate lumpy adjustment not only for that particular factor but also for other factors of production. Moreover, an interesting question in the context of developing and transition economies is whether the recent wave of market reforms has changed the nature of the adjustment process for manufacturers. Thus, in this paper, we also focus on how inter-related labor and capital adjustments changed after the introduction of market reforms in Colombia in the early 1990s.

Colombia is an interesting case to consider these issues. First, Colombia undertook substantial market reforms during the early 1990s, which were in part intended

¹Two exceptions, discussed more in detail below, are the studies by Polder et al. (2004) and Bloom (2006).

to liberalize labor and financial markets, and to facilitate factor adjustments. For example, in 1990 and 1991, the reforms reduced dismissal costs; liberalized deposit rates; eliminated credit subsidies; modernized capital market and banking legislation; removed restrictions on inflows of foreign direct investment, and greatly reduced barriers to imports. Second, Colombia has unique longitudinal microeconomic data on businesses. The main distinguishing feature of these data is that they have information on both plant-level quantities and prices for both outputs and inputs, which permits us to separately measure productivity, demand and cost shocks and to examine the impact of these shocks on factor adjustments. This is an innovation with respect to most of the existing literature, which measures productivity as the residual from a production function where physical output is proxied by revenue divided by a common industry-level deflator. The traditional productivity measures thus confound productivity differences across plants with within-industry price differences across plants. If prices reflect idiosyncratic demand shifts or market power variation rather than quality or other differences in product attributes, then productivity shocks as traditionally measured may not be related to technology or efficiency at all. By contrast, our physical output measures deflate revenue by plant-level prices so that we can separate productivity and price effects.

Our paper makes a number of methodological innovations. First, we analyze inter-related factor demands at the micro level in the presence of non-linear adjustment functions. This allows us not only to characterize the potential non-linearities in the adjustment of labor relative to capital at the micro level, but also to identify whether there are dynamic complementarities across factors. Second, our rich micro data contains plant-level output and input prices, with which we can estimate productivity and demand shocks, as well as key parameters. These are used along with input price shocks to estimate desired factor demands. We can thus examine how the gaps between the actual and desired adjustments of capital and labor depend on productivity, demand and cost shocks. One strength of our analysis is that we measure the desired factor levels by estimating directly the expressions resulting from the frictionless maximization problem. In particular, given data availability and our estimation method, in order to measure factor shortages or surpluses we do not have to resort to inference about the relationships between neither employment and hours nor fixed capital and energy utilization. As such, our estimated adjustment functions can be interpreted as reduced form relationships depicting the relationship between capital and labor adjustments and market fundamentals such as TFP and demand shocks. Under this interpretation, we are essentially asking whether these reduced form relationships are non-linear, whether they changed as a result of reforms, and whether the changes in these reduced form relationships after the reforms improved aggregate productivity through improved allocative efficiency.

We find strong evidence of non-linear micro adjustment, as businesses are much more likely to adjust capital and labor (or adjust by a greater amount) if the gaps between desired and actual levels are large. In addition, we find that capital and labor

adjustments tend to reinforce each other in that bigger capital shortages reduce hiring and bigger labor shortages reduce investment. Moreover, we find strong evidence that the reforms led to more flexible labor adjustment, especially on the job destruction side. Capital adjustment also became more flexible, but only in response to capital shortages. By contrast, plants facing surpluses of capital became less responsive. Even though frictions were reduced for both labor and capital adjustment, it seems that the impact was much larger on labor adjustment costs, which would have led producers to increase adjustment of labor and decrease adjustment of the more fixed capital input. Finally, we explore how the changes in factor adjustments affected allocative efficiency. We find that the reduction in frictions of labor and capital adjustments following the reforms had a positive but modest impact on allocative efficiency. On the other hand, we find that if adjustment frictions could be completely eliminated there would be a dramatic increase in productivity.

The paper proceeds as follows. In Section 2, we describe the institutional changes that led to factor market deregulation in Colombia. In Section 3, we set up the building blocks to estimate labor and capital adjustments under non-convex adjustment costs. Section 4 describes the data used to estimate the distributions of capital and labor shortages. In Section 5, we present evidence on the extent of heterogeneity and non-linearities in factor adjustments in Colombia, and on the evolution of these adjustments after the Colombian market reforms of 1991. In Section 6, we present decompositions of aggregate productivity which allow us to examine the impact of removing frictions in factor markets on productivity enhancing reallocation. We conclude in Section 7.

2 Market Deregulation in Colombia

In the early 1990s, the government of President Cesar Gaviria introduced important reforms to eliminate rigidities and enhance flexibility in factor and product markets.

Law 50 of December 1990 introduced severance payments savings accounts and reduced dismissal costs by between 60% and 80% (see, e.g., Kugler (1999, 2005)). In 1993, Law 100 changed the social security system by allowing voluntary transfers from a pay-as-you-go system to a fully-funded system with individual accounts, though this law also introduced a mandatory hike in employer and employee contributions up to 13.5% of salaries, of which 75% was paid by employers (see, e.g., Kugler and Kugler (2003)).

Other reforms sought to reduce frictions in financial markets. In 1990, Law 45 eliminated interest rate ceilings as well as requirements to invest in government securities, and lowered reserve requirements. At the same time, supervision of financial markets was reinforced in line with the Basle Accords for capitalization requirements. Law 9 of 1991 established the abolition of exchange controls eliminating the monopoly of the central bank on foreign exchange transactions and lowering substantially the extent of capital controls. Finally, Resolution 49 of 1991 eliminated restrictions to

foreign direct investment. This resolution established national treatment of foreign enterprises and eliminated limits on the transfer of profits abroad as well as bureaucratic procedures requiring the approval of individual projects by foreign firms (see, e.g., Kugler (2006)). This policy facilitated capital inflows in all sectors, but also induced entry of foreign banks increasing competition and lowering intermediation costs in the financial sector.

At the same time, international trade was largely liberalized. The Gaviria government accelerated the gradual decrease in tariffs initiated by the preceding Barco government, between 1986 and 1990. By the end of 1991, 99.9% of items were in the free import regime, nominal protection reached 14.4%, and effective protection 26.6%, down from 62.5% a year earlier (Edwards (2001)). In the late 1990s, the Samper government also made some progress in the areas of privatization and tax reform. However, the privatization process has been relatively limited in Colombia compared to the rest of Latin America and privatizations have been highly concentrated in the energy sector (Lora (2001)). Also, while efforts were made to increase tax collection and the neutrality of the tax system, Colombia's tax system remains one of the most distorted when compared to those of other Latin American countries (Lora (2001)).

If the goal of the reforms of enhancing allocative efficiency and reducing protection was achieved, then we should observe different patterns of factor adjustments between the 1980s and the 1990s, with increased flexibility of employment and capital adjustments after the reforms. In what follows, we consider the dynamics of factor adjustments before and after the reforms (pre- and post-1990), allowing for interdependence between employment growth and investment.

3 Theoretical Framework

This section explains the methodology we use to estimate adjustment hazards, as a function of the gaps between actual and desired levels of labor and capital, in the presence of either convex or non-convex adjustment costs. In turn, we propose a framework for deriving the desired factor demands, which are needed to estimate factor gaps.

3.1 Inter-related Adjustment Costs

Following Caballero, Engel and Haltiwanger (1995, 1997) (CEH hereafter), our theoretical framework is based on the observation that employment and capital are unlikely to equal their desired levels when they are subject to adjustment costs.² In the presence of costs of adjusting employment and capital, thus, plant j will face employment and capital shortages, Z_{jt} and X_{jt} at time t . We measure the employment shortage by

²These adjustment costs could be either due to regulations or due to technological frictions.

$$Z_{jt} = \frac{\frac{1}{3} L_{jt} - L_{jt-1}}{\frac{1}{2} (L_{jt} + L_{jt-1})}, \quad (1)$$

where L_{jt} is the desired level of employment, or the employment level if adjustment costs are momentarily removed, and L_{jt-1} is meant to capture employment after the shocks but before the plant has adjusted employment.³ Z_{jt} is naturally bounded between -2 and 2. Similarly, we measure the capital shortage by,

$$X_{jt} = \frac{\frac{1}{3} K_{jt} - K_{jt-1}}{\frac{1}{2} (K_{jt} + K_{jt-1})}, \quad (2)$$

where K_{jt} is the desired level of capital, or the level of capital if adjustment costs are momentarily removed, and K_{jt-1} captures capital after the shocks but before the plant has adjusted the capital stock. We define adjustment functions for employment and capital, $A_{jt}(Z_{jt}, X_{jt})$ and $B_{jt}(Z_{jt}, X_{jt})$, as the fraction of the respective shortage that is actually adjusted, and model them as a function of Z_{jt} and X_{jt} . That is, defining the actual adjustments of employment and capital as:

$$\Delta l_{jt} = \frac{L_{jt} - L_{jt-1}}{\frac{1}{2} (L_{jt} + L_{jt-1})} \quad (3)$$

and

$$\Delta k_{jt} = \frac{K_{jt} - K_{jt-1}}{\frac{1}{2} (K_{jt} + K_{jt-1})}, \quad (4)$$

the adjustment functions $A_{jt}(Z_{jt}, X_{jt})$ and $B_{jt}(Z_{jt}, X_{jt})$, which are also sometimes called “adjustment hazards” in the literature, are given by

$$A_{jt}(Z_{jt}, X_{jt}) = \frac{\Delta l_{jt}}{Z_{jt}}$$

and

$$B_{jt}(Z_{jt}, X_{jt}) = \frac{\Delta k_{jt}}{X_{jt}}.$$

The adjustment functions of employment and capital tell us something about the nature of adjustment costs.⁴ In particular, an employment adjustment function independent of the capital shortage, Z , and a capital adjustment function independent

³The adjustment measures we use are analogous to those developed and used by Davis, Haltiwanger and Schuh (1996) to study plant-level employment dynamics. The difference between two variables a and b divided by the average of a and b is a second-order approximation to the log first difference between a and b . An advantage of the Davis-Haltiwanger-Schuh measures is that they are symmetric and bounded, which reduces the potential for large outliers driving the results. Results are very similar if we use log first differences (not surprisingly, given the second-order approximation).

⁴Cooper and Willis (2003) raise questions about the use of measures of the gap between desired and actual factors to make structural inferences about the presence and magnitude of nonconvexities.

of the labor shortage, X , are consistent with quadratic adjustment costs or a partial adjustment model. By contrast, employment and capital adjustment functions that depend on Z and X , respectively, would be consistent with linear or lumpy adjustment costs or non-convexities.⁵ For instance, in the presence of fixed costs of adjustment, producers postpone adjustments until they are faced with large enough input shortages or surpluses. A key methodological contribution is to allow the employment adjustment function to depend on the capital gap, X , and the capital adjustment function to depend on the labor gap, Z , which would reveal non-convex dynamic interactions between capital and labor.⁶ Adjustment functions can be estimated either non-parametrically or parametrically as in Caballero and Engel (1993, 1999). Here we start with the following parametric specification:

$$\begin{aligned} A_{jt}(Z_{jt}, X_{jt}) &= \alpha_0 + \alpha_1 Z_{jt}^2 + \alpha_2 Z_{jt} \times X_{jt} + \alpha_3 X_{jt}^2, \\ B_{jt}(Z_{jt}, X_{jt}) &= \beta_0 + \beta_1 X_{jt}^2 + \beta_2 Z_{jt} \times X_{jt} + \beta_3 Z_{jt}^2. \end{aligned}$$

We modify this specification to permit the impact of Z on employment changes and X on capital changes to depend on the sign of Z and X (i.e., shortages and surpluses). We also permit the adjustment functions to vary across the pre- and post-reform periods. Since the adjustment functions $A_{jt}(Z_{jt}, X_{jt})$ and $B_{jt}(Z_{jt}, X_{jt})$ are poorly defined in the neighborhood of $Z_{jt} = 0$ and $X_{jt} = 0$, we re-write the adjustment function definitions and estimate the following equations at the micro-level with plant-level effects:

Even though, like CEH, we interpret adjustment functions that increase in the magnitude of the shortages as evidence consistent with nonconvexities, we can remain agnostic on the structural interpretation of the adjustment functions. In contrast to CEH, our results use a semi-reduced form specification allowing actual factor adjustment to be a nonlinear function of fundamentals (TFP and demand shocks), which we make explicit below. In this sense, we are not subject to the criticisms originally raised by Cooper and Willis (2003), since they are concerned in part with the approximations of shortages made by CEH (1997) given data limitations. Also, our semi-parametric estimation of the joint adjustment hazard is robust to aggregation problems that may arise in some structural estimation contexts, when the data are added over time, between production facilities and across different factor types.

⁵Caballero and Engel (1993,1999) develop the generalized (S,s) approach formally showing that models of nonconvexities imply a richer nonlinear relationship between adjustment and economic fundamentals as captured by the gap between desired and actual stocks.

⁶Previous studies of joint factor adjustment have generally relied on sectoral data and as such have assumed convex adjustment costs. Two recent exceptions are Polder, Pfann and Letterie (2004) and Bloom (2006). The paper by Polder et al. (2004) uses micro data for Denmark and assumes labor adjustment to be subject to convex adjustment costs. Contrary to our study, this study finds limited influence of spillovers from nonlinear capital adjustment to labor. The reason is that their estimates of labor adjustment costs are extremely high (in their view, even implausibly high), leaving little room for interaction. The paper by Bloom (2006) provides a structural framework to jointly estimate adjustment costs of labor and capital. Like our study, his study allows for asymmetries between investment and disinvestment on the capital side. However, since our framework is semi-parametric, we do not require identifying assumptions to estimate the adjustment cost function and we are able to consider flexible specifications.

$$\Delta l_{jt}(Z_{jt}, X_{jt}) = Z_{jt}A_{jt}(Z_{jt}, X_{jt}) = Z_{jt}[\alpha_0 + \alpha_1 Z_{jt}^2 + \alpha_2 Z_{jt} \times X_{jt} + \alpha_3 X_{jt}^2], \quad (5)$$

$$\Delta k_{jt}(Z_{jt}, X_{jt}) = X_{jt}B_{jt}(Z_{jt}, X_{jt}) = X_{jt}[\beta_0 + \beta_1 X_{jt}^2 + \beta_2 Z_{jt} \times X_{jt} + \beta_3 X_{jt}^2]. \quad (6)$$

In addition, since there is enormous heterogeneity in factor demands across establishments, we estimate these adjustment functions weighting establishments according to their factor use. That is, we weigh the labor adjustment function by establishment employment and the capital adjustment function by capital. This is done to account for the greater importance of the adjustments of large relative to small plants in determining aggregate adjustment.

In order to estimate the cross-section distribution of shortages and the adjustment functions, we first need to determine the desired levels of employment and capital. Given certain conditions, these can be proxied, up to a plant-specific constant, by the frictionless levels of employment and capital, where the frictionless levels are the levels that would be chosen absent any adjustment costs.⁷ In particular, the desired and frictionless levels relate to each other as follows:

$$\begin{aligned} L_{jt} &= \bar{L}_{jt} \kappa_j, \\ K_{jt} &= \bar{K}_{jt} \kappa_j, \end{aligned}$$

where \bar{L}_{jt} and \bar{K}_{jt} are the frictionless demands of employment and capital, and κ_j and κ_j are the plant-specific employment and capital constants (which may also capture measurement error). The frictionless levels of employment and capital will be determined in the next section by the first-order conditions of the plants' static optimization problem. Following CEH (1995, 1997), κ_j and κ_j can be determined as the ratio between the actual and the frictionless employment levels and the ratio between the actual and the frictionless capital stocks for the plants' median employment growth and investment, respectively, where median employment growth and investment are interpreted as reflecting replacement employment changes and investment. In other words, it is assumed that, in the year of a plant's median employment growth (investment), desired and actual adjustment of labor (capital) are equal.

3.2 Frictionless Profit Maximization

To determine the frictionless levels of employment and capital and to determine the plant-specific constants, we need to specify the plants' optimization problem and obtain the first-order conditions. The plant's production function is:

⁷CEH (1995) and Bertola and Caballero (1994) discuss the conditions under which these are reasonable approximations.

$$Y_{jt} = K_{jt} (L_{jt} H_{jt})^\alpha E_{jt} M_{jt} V_{jt}, \quad (7)$$

where K_{jt} is capital, L_{jt} is employment, H_{jt} are hours per worker, E_{jt} is energy use, M_{jt} are materials, and V_{jt} is a productivity shock.

There is an inverse demand for the product given by:

$$P_{jt} = Y_{jt}^{-\frac{1}{\epsilon}} D_{jt}, \quad (8)$$

where P_{jt} is the output price and D_{jt} is a demand shock and where $-\frac{1}{\epsilon}$ is the inverse of the elasticity of demand.

Finally, the firm faces competitive factor markets, where total labor costs, capital costs, energy costs and materials costs are:

$$\begin{aligned} L(L_{jt}, H_{jt}) &= w_{0t} L_{jt}^\beta + w_{1t} H_{jt}^{1-\beta} \\ \kappa(K_{jt}) &= R_t K_{jt}, \\ \epsilon(E_{jt}) &= P_{Et} E_{jt}, \\ M(M_{jt}) &= P_{Mt} M_{jt}, \end{aligned}$$

The wage function depends on the straight-time wage, w_{0t} , as well as on the overtime premium w_{1t} . The firm takes the user cost of capital, R_t , and energy and material prices, P_{Et} and P_{Mt} , as given.⁸

The state variables are the capital stock, the level of employment, hours, energy consumption, and materials that the plant would choose in the absence of frictions (i.e., the frictionless factor demands). These are equivalent to the observed levels of inputs when these are not subject to adjustment costs. We assume here that materials, energy and hours per worker all fall in this category, while we allow adjustment costs for capital and labor.

The firm maximizes frictionless profits by choosing capital, employment, hours, energy consumption, and materials, ignoring adjustment costs. The solution to the

⁸A point to note is that we are assuming that the underlying structural adjustment costs are external rather than internal (as defined by Lucas (1967) and Treadway (1969)). That is, the adjustment costs are separable costs in the profit maximization so that the production function depends on the levels of inputs and not on the changes in inputs. This approach permits us to both conceptually measure and estimate the desired levels of labor and capital using a standard Cobb-Douglas production function. While, like ours, most papers in the literature assume external adjustment costs, some progress has been made in the recent literature in terms of exploring the role of internal adjustment costs (e.g., Cooper and Haltiwanger (2006) and Cooper, Haltiwanger and Willis (2005)).

system of first-order conditions is given by two equations:⁹

$$\begin{aligned} \bar{E}_{jt} &= \frac{(\frac{-1}{-\tau})[\ln(\frac{-1}{-\tau}) - \theta_{jt}] - \vartheta_{jt} - \bar{\Pi}_{jt} - \bar{E}_{jt} - \bar{\mathcal{M}}_{jt} + (\frac{-1}{-\tau})^h \varpi_{0t} + \ln(1 + w_{1t} \bar{\Pi}_{jt}) - \ln \frac{i}{- \ln + \mathcal{R}_t}}{[+ - (\frac{-1}{-\tau})]}, \\ \bar{K}_{jt} &= \frac{(\frac{-1}{-\tau})[\ln(\frac{-1}{-\tau}) - \theta_{jt}] - \vartheta_{jt} - \bar{\Pi}_{jt} - \bar{E}_{jt} - \bar{\mathcal{M}}_{jt} + (\frac{-1}{-\tau})^h [\mathcal{R}_t - \ln \frac{i}{- \ln + \varpi_{0t} + \ln(1 + w_{1t} \bar{\Pi}_{jt})}]}{[+ - (\frac{-1}{-\tau})]}, \end{aligned} \quad (9)$$

where ϑ denotes the natural logarithm of variable y . That is, the optimal employment and capital levels depend on the levels of hours, energy, and materials; on factor and demand elasticities, and on productivity and demand shocks.¹⁰ Thus, a novelty of our approach relative to other studies using the gap methodology is that we explicitly estimate optimal employment and capital levels and allow them to depend on plant-specific demand- and supply-side shocks.

Frictionless levels in equation (9) are estimated numerically by substituting the various parameters of the model, calculated as explained below. Then, taking the exponential of the logarithms of frictionless employment and capital, we obtain desired employment and capital. Finally, we use these to calculate our employment and capital shortages, Z_{jt} and X_{jt} , and in turn to estimate the adjustment functions.

3.3 Estimation

The system of equations above can be estimated numerically by obtaining the parameters, α , β , γ , δ , η , and ν as well as the productivity and demand shocks, ϑ_{jt} and $\bar{\mathcal{D}}_{jt}$, and input prices, \mathcal{R}_t , ϖ_{0t} , and ϖ_{1t} . The strategies we follow to estimate factor and demand elasticities (α , β , γ , δ , η) are explained in Section 4. We use those estimates to calculate ϑ_{jt} and $\bar{\mathcal{D}}_{jt}$, as residuals from the production function and the demand function, respectively. For the user cost of capital, \mathcal{R}_t , the results we report use a constant value, 0.15, which is in the lower bound of previous estimates for Colombia. The straight-time wage, ϖ_{0t} , is a sector-level wage calculated as explained in Section 4 and the overtime premium, ϖ_{1t} , is set to the legally required overtime premium of 25% in Colombia. Materials, energy and hours are measured as explained in Section 4. The only missing parameter is ν . Both *Bils (1987)* and *Cooper and Willis (2003)* estimate a ν of 2 for the U.S. We use this value of the parameter as an approximation.¹¹

⁹See the Appendix for the full derivation of the first-order conditions.

¹⁰We do not make any assumptions about the distributions of productivity and demand shocks. If these were i.i.d. then optimal factor demands would not be functions of either. In practice, as we indicate below, our estimated productivity and demand shocks display quite a bit of persistence.

¹¹We tried different values of ν , ranging from $\nu = 1$ to $\nu = 5$. Results are robust to the use of these alternative values. We also tried other estimates of \mathcal{R}_t , both constant and variable, which yield similar results. The robustness of the results to changes in \mathcal{R}_t is reassuring, given that by not properly measuring \mathcal{R}_t we may be missing part of the effects of reforms on allocative efficiency. For instance, the reforms may have affected capital market imperfections, which in turn may be

4 Data Description

Our data come from the Colombian Annual Manufacturers Survey (AMS) for the years 1982 to 1998. The AMS is an unbalanced panel of Colombian plants with more than 10 employees, or sales above a certain limit (around US\$35,000 in 1998).¹² The AMS includes information for each plant on: the value of output and average prices charged for each product manufactured (products are reported at the 8-digit ISIC level); overall cost and average prices paid for each material used in the production process; energy consumption in physical units and average energy prices; production and non-production number of workers and payroll; and book values of equipment and structures.¹³ The database also provides information on plant location (state) as well as industry classification codes (at the 5-digit ISIC level).

To implement the methodology explained above we need a rich source of information at the plant level. In particular, we need measures of factor use, productivity and demand shocks, and input prices. We describe below the construction of these variables. A more thorough description of the database can be found in Eslava et al. (2004).

4.1 Plant-level Factor Use

Our methodology requires measuring the demand of energy, materials, capital, and labor hours at the plant level. Quantities of energy consumption are directly reported by the plant. We construct quantities of materials used by the plant by dividing the cost of materials by a price index for materials, which we construct at the plant level.¹⁴ An important advantage of our data with respect to other sources is the availability of plant level prices. Using plant level price indices as deflators eliminates a common source of measurement error.

associated with idiosyncratic variation in the user cost of capital.

¹²The methodology used to establish longitudinal linkages to follow plants over time is described in detail in the Appendix to Eslava et al. (2004).

¹³One limitation in the current context is that the data are annual and so we are subject to time aggregation issues (see, e.g., Hamermesh (1993) and Hamermesh and Pfann (1996) for an excellent discussion of time aggregation). Since we consider a flexible functional form for our adjustment functions, and do not attempt to identify the underlying structure of adjustment costs, this mitigates the concerns about time aggregation.

¹⁴The construction of plant-level materials price indices is explained in detail in Eslava et al. (2004). Those indices are generated from weighted averages of the price changes of all individual materials used by the plant. The weight assigned to each input corresponds to the average share (over the whole period) of that input in the total value of materials used by the plant. Plant-level price indices are then generated recursively from these price changes. Given the recursive method used to construct the price indices and the fact that we do not have plant-level information for material prices for the years before plants enter the sample, we impute material prices for each plant with missing values by using the average prices in their sector, location, and year. When the information is not available by location, we impute the national average in the sector for that year.

The plant capital stock (which includes equipment and buildings) is constructed recursively using a perpetual inventory method:

$$K_{jt} = (1 - \delta) K_{jt-1} + \frac{I_{jt}}{P_{1t}}$$

for all t such that $K_{jt-1} > 0$, where I_{jt} is gross investment, δ is the depreciation rate and P_{1t} is a deflator for gross capital formation. For each plant, we initialize the series at the book value reported in the first year the plant appears in the sample. Our measure of P_{1t} is the implicit deflator for capital formation from the input-output matrices for years 1982-1994, and from the output utilization matrices for later years. We use the depreciation rates calculated by Pombo (1999) at the 3-digit sectoral level, which range between 8.7% and 17.7% for machinery and between 2.4% and 9.8% for buildings. Gross investment is generated from the information on fixed assets reported by each plant and can be positive or negative.

Finally, since the AMS does not have data on hours per worker (only employment), we construct a measure of hours per worker at time t for sector $G(j)$, to which plant j belongs, as,

$$H_{jt} = \frac{\text{earnings}_{G(j)t}}{W_{G(j)t}},$$

where $W_{G(j)t}$ is a measure of sectoral wages at the 3-digit level from the Monthly Manufacturing Survey, and $\text{earnings}_{G(j)t}$ is a measure of earnings per worker constructed using the AMS data, where

$$\text{earnings}_{G(j)t} = \frac{\sum_{j \in G} P_j \text{payroll}_{jt}}{\sum_{j \in G} L_{jt}}.$$

The sector-level nominal wage for year t and sector G is constructed as the weighted average of the wages of non-production and production workers, where the weights are respectively the share of administrative employees and the share of production employees in the total number of employees in year t for the average plant in sector G . Finally, the real wage, $W_{G(j)t}$, is equal to the nominal wage deflated using the CPI.¹⁵

4.2 Descriptive Statistics of Prices and Quantities

Table 1 presents descriptive statistics of the quantity and price variables just described, weighted by output, for the pre- and post-reform periods. The quantity variables are expressed in logs, while the prices are relative to a yearly producer price index to discount inflation. We also include summary statistics of the output and

¹⁵By using a sectoral wage index, we are attributing plant-specific differences in wages from the sectoral average to differences in labor quality at the plant.

output price measures used to estimate productivity and demand shocks as well as factor and demand elasticities.¹⁶ Both output and the use of all factors increased between the pre- and post-reform periods. Relative prices of output and materials prices declined between the pre- and post-reform periods, while energy prices and wages increased.¹⁷

4.3 Productivity and Demand Shocks

Our calculations of desired factor demands also require measures of productivity and demand shocks, as well as estimated factor elasticities and demand elasticities. We use two different sets of estimated factor elasticities. The first is the set of estimates generated by Eslava et al. (2004), from the same data we use for this paper. Those elasticities are estimated using an Instrumental Variable approach to address the issue of factor demands being potentially endogenous to productivity shocks. The estimated factor elasticities do not vary across sectors in this case, because some of the instruments used to estimate the production function vary only across sectors. The second set of factor elasticities we use corresponds to cost shares estimated at the 3-digit level, where the capital cost share is calculated as a residual after assuming constant returns to scale. Total factor productivity is calculated as the (log) residual of the production function, using the estimates of factor elasticities. We generate two sets of results, one with each set of estimated factor elasticities and resulting TFP measures. To avoid overcrowding the tables, we only report results that use the factor elasticities estimated by Eslava et al. (2004). However, all of our results are robust to the use of elasticities obtained from a cost shares approach.¹⁸ Table 1 shows that average productivity and the dispersion of productivity went up during the reform period. It is also worth mentioning that the productivity estimates display a lot of persistence, i.e., the AR(1) coefficient for TFP is around 0.92.

To obtain demand elasticities and establishment-level demand shocks, we estimate the (log) inverse-demand equation (8). Given the potential endogeneity of plant level prices with respect to demand shocks, we estimate the demand equation using

¹⁶The output measure we report is also deflated using a plant-level price index, constructed following the same strategy used for materials prices.

¹⁷Caution needs to be used in interpreting mean relative prices in this context since the relative price at the micro level is the log difference between the plant-level price and the log of the aggregate PPI. On an appropriately output weighted basis, the mean of this relative price measure should be close to zero in all periods since the PPI is dominated by manufacturing industries. The larger difference with respect to PPI in the post-reform period reflects that the growth of manufacturing prices fell more rapidly than that of other prices in the economy, possibly due to the fact that external competition introduced by the reforms affected the manufacturing sector more than others.

¹⁸The alternative set of results is available from the authors upon request. The correlation between the TFP calculated with our IV approach and the TFP calculated with a cost-share approach is very high, 0.88. Moreover, the standard deviations of the two TFP measures are about the same, and their correlations with other key variables (e.g., plant-level prices) are very similar.

a two-step procedure.¹⁹ In particular, we follow Eslava et al. (2004) by using total factor productivity as an instrument in our demand estimations. Our demand shock measure is the (log) residual from the demand equation, calculated using the estimated demand elasticities.²⁰ Table 1 shows the mean and standard deviation of the demand shock measures for the pre- and post-reform periods. While demand shocks fell on average, their dispersion increased after the reforms. Like productivity shocks, demand shocks are very persistent, i.e., they have an AR(1) coefficient of around 0.99.²¹

5 Labor and Capital Adjustments

We now examine the patterns of capital and labor adjustments. Before turning to the estimates of adjustment functions, Table 1 presents the first moments of the distributions of labor and capital shortages, before and after the reforms for the sample of pairwise continuers (i.e., all plants that are present in $t-1$ and t).²² Table 1 shows that mean labor and capital shortages move closer to zero in the post-reform period. These movements suggest plants were closer to their desired labor and capital levels during this period, consistent with greater flexibility in markets after the reforms. The second moments for labor and capital shortages do not change much between the two periods. These findings are particularly striking given the increased variability in the underlying factors (TFP, demand shocks, input prices) between the two decades. The dispersion of labor and capital shortages thus falls relative to the dispersion of shocks faced by plants, also suggesting greater flexibility after reforms. Therefore, this preliminary evidence points to increased flexibility in factor markets. We now turn to an investigation of the changing patterns of adjustment.

¹⁹We only report results using a uniform demand elasticity across sectors and time. However, the correlation between our demand shock measures estimated imposing a uniform elasticity and our demand shock measures estimated allowing for different elasticities during the pre- and post-reform period is 0.97. While the demand shock measures differ more when allowing elasticities to vary by sector, all of our results below are robust to the use of demand shocks which take away sectoral differences in elasticities. Results are available upon request.

²⁰While we call the residual from this inverse-demand regression a demand shock, it is possible that this residual captures relative price shocks due to both differences in market power and differences in product quality across plants. For both interpretations, however, higher demand should lead establishments to demand more inputs.

²¹The AR(1) coefficients are simply obtained by regressing TFP and demand on their respective lags. Results are available upon request from the authors.

²²The focus of the current paper is on capital and labor adjustment for continuing businesses. In Eslava et al. (2006) we focus on the impact of reforms on plant exit. We find evidence that market reforms increased the relative importance of market fundamentals (TFP, demand and costs) in inducing exit. We leave for future work the exploration of the impact of market reforms on plant entry as well as a fully integrated approach that would permit the study of all margins of adjustment. We note that the literature on capital and labor adjustment focuses primarily on continuing businesses.

5.1 Adjustment Functions

Table 2 and Figures 1 and 2 present estimates of the labor and capital parametric adjustment functions using equations (5) and (6). As a benchmark, Table 2 also reports results from estimating a standard partial adjustment model (PAM), in which changes in labor and capital are independent of the magnitude and sign of shortages, so that establishments always close a constant fraction of the gap. Comparing the results of this specification to those of the non-linear models (5) and (6) allows us to explore the importance of permitting non-linearities.

The weighted employment adjustment function, $A = \frac{4l_{jt}}{Z_{jt}}$, is depicted in Figure 1 as a function of the labor shortage, Z , setting the capital shortage at $X = 0$, X at one standard deviation, and X at minus one standard deviation, where the weights are the labor demands. Similarly, Figure 2 depicts the weighted capital adjustment function, $B = \frac{4k_{jt}}{X_{jt}}$, as a function of the capital shortage, X , setting the labor shortage at $Z = 0$, Z at one standard deviation, and Z at minus one standard deviation, where the weights are the demands for capital.²³ Figures 1 and 2 also show the fraction of employment and the capital stock, respectively, represented by the plants located at different levels of the shortages. We focus our attention on the region of the shortage distributions where most plants are located, by truncating these figures at shortages of -1.35 and 1.35. About 90% of aggregate employment and 90% of the aggregate capital stock are concentrated in these regions. Similar figures covering the full range of shortages are included in the Appendix.

Consistent with the previous literature, Figures 1 and 2 show highly non-linear adjustment. Table 2 shows that the non-linear terms as well as the terms capturing asymmetries for positive and negative shortages are not only economically but also statistically significant. A standard linear PAM specification, thus, would miss key aspects of the adjustment process captured by our more flexible non-linear and asymmetric specification. There are, indeed, striking asymmetries between positive and negative adjustments, as well as important differences in adjustments at different regions of the distributions of shortages. Figure 1 shows that labor adjustment is a non-linear function of the gap when faced with employment shortages but not with surpluses. We find that an increase in the shortage from 0 to one standard deviation (close to 0.65) implies an increase in the adjustment rate of about 5 percentage points from an initial level of around 14%, while moving to a shortage of 1.75 basically doubles the adjustment rate. No similar increase is observed for plants faced with employment surpluses. This may be because one of the most important costs of separations are the severance payments imposed by regulations. These are per worker costs as opposed to a fixed costs, which would generate non-linearities in adjustments to surpluses.

By contrast, for capital, we find non-linearities on both the creation and destruc-

²³Results with and without weights are very similar. As discussed in a footnote below, the only important difference arises when estimating the effects of reforms on investment.

tion sides. Figure 2 shows that plants with larger gaps between the desired and actual levels of capital adjust more. We find that moving from a gap of 0 to a gap of 0.7 in absolute value (a change of about one standard deviation) implies an increase in the adjustment rate of close to 5 percentage points, from initial levels of around 0 for surpluses and around 20% for shortages. In addition, we find clear evidence of irreversibilities for capital on the destruction side as capital shedding is much less likely than investment, even in the presence of large capital surpluses.

Generally, our results are consistent with the findings in CEH (1995, 1997) for the U.S. who also find evidence of non-linear adjustment for capital and employment separately. Moreover, the finding of irreversibility in capital formation is consistent with the evidence by Caballero and Engel (1999) and Cooper and Haltiwanger (2006) who find that both convex and non-convex costs of adjusting, as well as irreversibilities, are all important components of capital adjustment cost functions in the U.S.

Our specifications are more general than those in previous studies, since we consider the joint adjustments of employment and capital, allowing us to study the effects of capital shortages on employment adjustment and of employment shortages on capital adjustment. Figure 1 shows that while higher capital shortages (e.g., increasing X by one standard deviation) reduce the pace of job creation, they do not have a large effect on employment adjustment on the destruction side.²⁴ On the other hand, Figure 2 shows that greater labor shortages lead to less investment when there is a capital shortage, while greater labor surpluses make firms less likely to shed excess capital. In this respect, capital and labor frictions appear to be dynamic complements as they reinforce each other (i.e., less adjustment in one factor leads to less adjustment on the other and vice-versa).

Before proceeding to our analysis of the effects of reforms, it is important to emphasize that taking a flexible non-linear approach towards estimation of the adjustment dynamics is critical in this context. First, the adjustment of one factor depends not only on the gap between actual and desired levels of that factor, but also on the gap of the other factor. Second, the shapes of the adjustment functions are highly non-linear with important asymmetries for positive and negative shortages and important cross effects. Thus, using our generalized approach is critical for understanding the patterns of adjustment in general and, as we will see, in particular, for studying the impact of the reforms.

Also, as we have noted, since our gap measures are functions of TFP and demand and cost shocks, our estimated adjustment functions can be interpreted as reduced form relationships between capital and labor adjustments and market fundamentals.

²⁴The fact that capital shortages inhibit job creation is consistent with the finding by Caballero, Engel and Micco (2004) that in Colombia, and other Latin American economies, large firms display more pronounced non-linearities in their propensity to adjust employment, which in turn lowers their probability of facing large labor shortages. Large producers in their sample are less likely to face financial constraints to invest and are, therefore, less likely to exhibit large capital shortages too.

It is clear that a non-linear reduced form relationship dominates a linear relationship and, as we will see below, the effect of market reforms is sensitive to the nature of these non-linear relationships as well. Moreover, the findings in Table 2 are supportive of the semi-reduced form interpretation of our estimation, given the observed statistically significant relationships between capital and labor adjustment and measured shortages and surpluses. For example, our results show clearly that a firm with a positive measured shortage tends to increase employment on average while a firm with a positive surplus tends to decrease employment. Similar remarks apply to capital adjustment.

5.2 Adjustments after Deregulation

The reforms had a substantial impact on the patterns of labor and capital adjustments. Figure 3.a shows substantially more employment adjustment on the destruction side after dismissal costs were reduced in 1990. In particular, we find that plants faced with employment surpluses multiplied their adjustment rate for employment by about 1.5 after the reforms. On the creation side, there is less adjustment for small shortages but substantially more for shortages above a threshold, implying more important non-linearities after the reforms. This is consistent with reforms making fixed costs of increasing the labor force relatively more important, and thus suggests that fixed costs in this margin are more technological than institutional in nature. A more regulated environment seems to be associated to hiring costs, but only of the convex type. The finding of more non-linear employment growth after reforms is also consistent with greater job creation in response to large labor shortages after credit constraints were relaxed and capital shortages reduced following financial liberalization.²⁵ We find that a plant facing a 0.05 employment shortage shows a reduction in the adjustment rate from close to 15% to about 13%, while a plant with an employment shortage of 1.35 exhibits a large increase in the adjustment rate from 20% to almost 30%. The finding of greater labor market flexibility is not surprising given that the labor market reform of 1990 intended to eliminate distortions on dismissals and hiring by reducing dismissal costs. The estimated coefficients in Table 2 show that these effects are statistically significant and show that the linear PAM model misses most of this story. That is, although the PAM model (Column (2)) shows a greater adjustment coefficient post-reform it cannot capture the fact that this result is being driven by a large increase in adjustment on the destruction side and an increase on the creation side only for large shortages.

Figure 3.b shows striking differences in terms of the impact of reforms on the creation and destruction of capital. There is much less capital destruction after the reforms. By contrast, for the most part, the responsiveness of investment increases after the reforms. Moreover, the effect of reforms on investment is non-linear: the

²⁵Indeed, as Figure 1 illustrates, higher capital shortages are associated with less pronounced non-linearities in response to labor shortages.

investment function becomes flat, showing that the increased responsiveness of investment is limited to small shortages. Investment only becomes less responsive to capital shortages at very large shortages, but this decreased flexibility has little aggregate impact given that the share of capital facing large capital shortages is only about 10%.

The greater responsiveness of capital adjustment to shortages is consistent with reforms yielding greater flexibility. However, less adjustment to capital surpluses after the reforms is at odds with the expectation of greater flexibility. We are uncertain as to what is driving this pattern, but note that post-reform the capital adjustment patterns closely mimic the irreversibility observed in healthy market economies like the U.S. (see, in particular, CEH (1995) and Cooper and Haltiwanger (2006)). The greater irreversibility may also reflect a substitution towards job destruction and away from capital destruction. Perhaps, prior to reforms firms used capital destruction more readily in spite of technological and market barriers that yield irreversibility (e.g., lower selling prices for capital than for buying capital), while reforms made job destruction a relatively cheaper way of getting rid of factors.

As mentioned, we also find that the response to capital shortages is less non-linear after the reforms. Taken literally this result implies that before the reforms, it took a very large capital shortage for a firm to adjust. Such non-linearities could arise from several factors including fixed costs as well as factors outside the model such as credit market constraints. It may have been that the reforms reduced fixed costs associated with capital expenditures. This is not implausible: for instance, there may be barriers to importing capital goods that were removed or reduced by the trade reform. Moreover, credit market constraints could act to deter capital expenditures in response to shortages, in a manner similar to adjustment costs; such constraints would be most relevant for firms with capital shortages as opposed to capital surpluses (although capital market constraints would also likely impact the secondary market for capital goods). Stringent liquidity constraints pre-reform existed in terms of both regulations of financial markets and capital controls.²⁶

It is also worth noting that in examining the estimated coefficients in Table 3 the changes in coefficients are statistically significant and the PAM model interacted with the reform dummy misses most of the story. The linear PAM model interacted with the reform dummy (Column (6)) suggests less adjustment of capital after the reforms. This misses the fact that there has been an important increase in responsiveness to positive capital shortages, while the reduction in capital adjustment is concentrated in establishments with excess capital.

²⁶It is worth noting, however, that we do not find this increase in investment if the capital adjustment function is estimated without giving different weights to plants with different levels of factor use. It would thus seem that the increase in investment post-reform is most important for larger plants. The change in investment patterns could only be explained by the removal of liquidity constraints if these disappear mainly for large plants. All other results, however, are robust to estimating adjustment functions without using weights.

Up to this point, we have discussed changes in the patterns of adjustment between the pre- and the post-reform periods, and have attributed those changes to the reform process. One valid question is whether the reforms are truly behind the observed changes, or maybe other, contemporaneous, forces are at work. To try to partly get at this question, we allow the adjustment function to vary with an index of overall reform for the Colombian economy.²⁷ The reform index, which varies yearly, measures the degree of market orientation in the areas of labor regulation, financial sector regulation, trade openness, privatization and taxation. Our index of reform is generated using the data on institutions collected by Lora (2001).²⁸ Figure 5 presents the index, which has an increasing trend over the period, with an important discrete increase at the beginning of the 1990s.

The results, letting the adjustment functions vary with this measure of reform, are illustrated in Figures 4.a and 4.b, which show adjustment functions at three different levels of the reform index. Consistent with our interpretation of the findings in Figures 3.a and 3.a, we find that increased market orientation yields more employment adjustment on the destruction side and more pronounced non-linearity of employment adjustment on the creation side. Similarly, greater movement towards reforms seems to be associated with less capital shedding, and a higher and flatter capital formation function. The reform index, thus, is found to have effects on the patterns of adjustment in the same direction as the simple pre- and post-reform comparisons.²⁹ In summary, the deregulation of markets appears to have impacted the non-linear adjustments of labor and capital in rich ways – that is, the results suggest that the deregulation did not yield simple shifts of the adjustment functions

²⁷In practice, we do this by interacting each term of the adjustment function with the reform index, rather than the reform dummy. Since the series for the index starts only in 1985, our estimations with the index are restricted to the 1985-1998 period.

²⁸Following Lora (2001), we generate indices of market reform in each of the five areas mentioned above, and then average those individual indices to construct the index of overall reform. However, Lora (2001) calculates the individual indices in a 0-1 scale, where 0 (1) corresponds to the most (least) rigid institutions in Latin America over the period for each of the five categories that compose the aggregate index. We use a different 0-1 scale, where the index in each category is calculated relative to the minimum and maximum level of reform in Colombia during the period, rather than the minimum and maximum relative to neighboring countries as calculated in the Lora index.

²⁹Having shown this, it is important to note that not all the time variation in the patterns of adjustment may be attributed to changes in regulations, as captured by the reform index. Adjustment patterns may also change as a reflection of the existence of stochastic adjustment costs, or changes of adjustment costs attributable to cyclical (possibly aggregate) shocks, rather than persistent institutional change. To check for this, we estimate adjustment functions year-to-year. Results of this exercise (available upon request) show that market orientation as captured by the reform index seems to largely account for changes in the shape of the adjustment functions, though it does not capture all the shifts in levels. It is important to note that, despite the clear importance of cyclical factors, the same general patterns described for the pre- and post-reform periods are evident in the year-to-year adjustment functions. In particular, the post-1990 years are characterized by a more pronounced nonlinearity of adjustment on the job creation side, more job destruction, and less capital shedding.

but rather impacted positive and negative shortages differently, linear and non-linear terms differently and cross terms differently.

6 Factor Reallocation and Aggregate Productivity

In this section, we examine whether there were productivity gains associated with the changes in labor and capital adjustments observed after the reforms. In particular, we measure changes in aggregate productivity due to changes in reallocation from the reduction or removal of frictions in factor markets. We conduct this exercise by using a cross-sectional decomposition methodology, first introduced by Olley and Pakes (1996). We quantify what part of aggregate productivity every year reflects the productivity of the average plant, and what part captures the concentration of activity in the more productive plants, by conducting the following decomposition of aggregate TFP:

$$TFP_t = \overline{TFP}_t + \sum_{j=1}^3 f_{jt} - \bar{f}_t \left(TFP_{jt} - \overline{TFP}_t \right),$$

where TFP_t is the aggregate total factor productivity measure for a given 3-digit manufacturing sector in year t . These aggregate measures correspond to weighted averages of our plant-level TFP measures, where the weights are market shares (calculated as described below). The first term of the decomposition, \overline{TFP}_t , is the average cross-sectional (unweighted) mean of total factor productivity across all plants in that sector in year t . TFP_{jt} is the total factor productivity measure of plant j at time t estimated as described in Section 5, f_{jt} is the share or fraction of plant j 's output out of sectoral output at the 3-digit level in year t , and \bar{f}_t is the cross-sectional unweighted mean of f_{jt} for the sector.³⁰ The second term in this decomposition allows us to understand whether production is disproportionately located at high-productivity plants, and examining this decomposition over time allows us to learn whether the cross-sectional allocation of activity has changed in response to the market reforms.³¹

We estimate the actual decomposition of TFP and then we construct four counterfactuals, which allow us to answer what would had been the cross-sectional allocation had frictions in factor markets been removed altogether or, alternatively, reduced to the post-reform levels. The decompositions only differ from each other in the shares

³⁰The fact that we calculate aggregate measures at the sector level means that our focus is on within-sector reallocation rather than between-sector reallocation, for sectors defined at the 3-digit level. For measurement and conceptual reasons, comparisons of TFP across sectors (in levels) are more problematic to interpret. Focusing on within-sector allocation permits us to emphasize the degree to which market reforms have led to an improved allocation of activity across businesses due to less distortions in factor markets and the associated higher competition.

³¹An advantage of this cross-sectional method over methods that decompose changes in productivity over time, is that cross-sectional differences in productivity are more persistent and less dominated by measurement error or transitory shocks.

used in the second term. The first decomposition uses actual output shares. The other decompositions use counter-factual output shares, where output is calculated as:

$$\psi_{jt} = \mathcal{R}_{jt}^b \hat{\mathcal{L}}_{jt}^3 H_{jt} \hat{E}_{jt}^b M_{jt}^b \psi_{jt} \quad (10)$$

In each case, the levels of energy, hours, and materials are the observed ones, and the ψ_{jt} is the exponential of our TFP measure. The levels \mathcal{R}_{jt} and $\hat{\mathcal{L}}_{jt}$, however, vary across decompositions. For the second decomposition, \mathcal{R}_{jt} and $\hat{\mathcal{L}}_{jt}$ are the frictionless levels of capital and labor.³² For the third decomposition, \mathcal{R}_{jt} and $\hat{\mathcal{L}}_{jt}$ are the capital and employment levels that would had resulted if labor and capital changed according to our estimated adjustment functions in equations (5) and (6), which vary between the pre- and post-reform periods. Finally, for the last two decompositions, we construct counter-factual shares where $\hat{\mathcal{L}}_{jt}$ and \mathcal{R}_{jt} are the employment and capital levels that would have prevailed if the labor and capital adjustment functions, respectively, had remained the entire period as during the pre-reform years.

Figure 6 presents the results of this decomposition. The thin solid line corresponds to the $\overline{\text{TFP}}_t$ term (equal across the different versions of the decomposition), while the other lines represent the second term, named “cross term” using shares from the different measures of output. The cross term of the actual decomposition, represented by the dotted line, shows that allocative efficiency improved after the introduction of reforms in 1991, increasing aggregate productivity.

The thick grey line presents the cross term of the frictionless decomposition, which shows what productivity levels would have been had all frictions in factor adjustment been removed. Comparing this line with the cross term of the actual decomposition shows that productivity would have been substantially higher in all years had all frictions from factor markets been removed. The difference is quite large: the cross term is about 25% lower than it would be in the absence of barriers to efficient allocation. Since the average TFP is identical in both decompositions by construction, this gain from the removal of frictions translate into an equal gain in aggregate productivity. This increase is due to the fact that allowing plants to adjust labor and capital more easily increases the market share of more productive plants and reduces the share of less productive plants. Note that we also find that allocative efficiency would have improved over the 1990s even in a frictionless environment. This result, which may seem surprising given that all possible barriers to allocation from factor adjustment costs were removed by construction for all periods, is associated with the greater dispersion of TFP across firms following the reforms as reported in Table 1. The scope for gains from improved allocation depends on the volatility of the shocks faced

³²For all counter-factuals, we estimate the levels of capital and labor, and thus their respective adjustments, holding the demand shocks at their average level for each plant. We do this in order to hold constant any potential independent effect of demand changes on reallocation during the period of reforms. We have also conducted the counterfactuals allowing demand shocks to vary and the results are very similar, suggesting that demand changes, on their own, do not play a crucial role in reallocating activity from low- towards high-productivity plants.

by plants; flexibility is advantageous only to the extent that plants need to adjust to shocks. If shocks are larger and more frequent, the benefits of being able to adjust are also larger. It also may be that other barriers to efficient allocation other than reductions in factor adjustment costs (and thus outside of our model) were reduced due to the reforms and this is reflected in the improved allocative efficiency in the frictionless case.

The remaining counter-factual decompositions allow answering whether the Colombian reforms moved the economy in the direction of a frictionless environment. From Figure 6, it is clear that the impact of reforms on aggregate productivity was small. The cross term is almost identical between the decomposition that uses output projected by our adjustment function (in circles in the figure) and those that use output projected by keeping one of the adjustment functions at its pre-reform level. The differences between these three scenarios are very small.

To discuss these differences, we report the results of our counter-factual exercises in Table 3. Column (1) shows the counter-factual cross-term corresponding to the third decomposition, when both labor and capital are allowed to adjust to the post-reform levels. Columns (2) and (3) correspond to the counter-factual cross-term corresponding to the fourth and fifth decompositions, in which labor and capital are kept at their pre-reform levels, respectively. We focus on the 1990s since, by construction, our projected output shares are identical in the pre-reform period. We first keep the employment adjustment function as during the pre-reform period but allow the capital adjustment function to change (Column (2)), and we then keep the capital adjustment function as during the pre-reform period but allow the labor adjustment function to change (Column (3)). The cross-term is uniformly lower in Column (2) compared to Column (1), reflecting the cost of decreased capital flexibility. By contrast, the results for the last decomposition in Column (3) show that productivity and the cross-section term are bigger when only labor adjustment is allowed to change after the reforms compared to when both labor and capital are allowed to change. Our results, thus, suggest that the reforms, and most likely the labor market reform, contributed to increase productivity by reallocating activity from low-towards high-productivity plants as labor adjustments moved closer to their desired levels. As mentioned above, however, the counter-factual suggests that the impact of the reforms on allocative efficiency via the change in the labor adjustment function is very small.

Overall, our analysis of counter-factuals suggest that frictions in terms of capital and labor adjustment are potentially very important as removal of all such frictions would yield a substantial increase in productivity. While our results in prior sections suggest there are statistically and economically significant changes in the adjustment functions following the reforms, the direct impact of these changes in the adjustment functions on allocative efficiency is quite small. However, all of the counter-factuals (as well as the decomposition using the actual data) show a substantial improvement in allocative efficiency following reforms so it does appear that these had an impact

on allocative efficiency possibly through channels other than input reallocation. Part of the explanation appears to be a greater scope for allocative efficiency, given the increased dispersion of productivity shocks after the reforms. The remainder is presumably the reduction of frictions other than capital and labor adjustment costs.

7 Conclusion

In this paper, we examine how plant-level adjustment dynamics for capital and labor interact with each other. Given the widespread finding that plant-level adjustments are lumpy, we allow for non-linear adjustment dynamics. Beyond considering the interaction of capital and labor adjustments, we estimate adjustment dynamics in the context of an emerging economy, namely Colombia, that has undergone a substantial reform process intended to deregulate markets. In particular, an important objective of structural reforms in Colombia and other developing economies during the 1990s was to make factor markets more flexible.

Our results can be briefly summarized as follows. First, consistent with the existing literature, we find strong evidence of non-linear micro adjustment. Businesses are likely to adjust capital and labor by a proportionally greater amount if the gaps between desired and actual levels are large. Equivalently, we find larger proportionate responses to large TFP and demand and cost shocks than in response to small shocks. Second, we find important interactions between capital and labor adjustments. In particular, businesses with capital shortages are less likely to create jobs in response to labor shortages, and businesses with labor shortages are less likely to invest as a result of capital shortages. Similarly, businesses with surplus labor are less likely to shed excess capital. These findings highlight the importance of jointly analyzing capital and labor adjustments. In terms of policy, the evidence highlights a potentially undesirable feature of piecemeal reform, namely that frictions in still regulated factor markets can distort adjustment of a newly deregulated factor, thus hampering the effectiveness of reform.

In terms of the impact of market reforms, the most dramatic effect we find is the increased flexibility of labor especially on the destruction side. Interestingly, this increase in labor flexibility is accompanied by a milder but significant reduction in capital destruction. Thus, while the reforms may have succeeded in making labor more flexible in Colombia, plants appear to have used that greater flexibility of labor to reduce capital adjustments. One possible explanation for this pattern is that the reduction in frictions from the institutional reform may increase the importance of technology-related frictions. Generally, technological frictions associated with labor rotation are smaller than those associated with retooling or scrapping capital. In the absence of distortions, producers would rather respond to shocks through the adjustment of labor, as the more variable factor, as opposed to through the adjustment of fixed capital.

Our analysis shows that most of the findings with regards to labor and capi-

tal adjustments would be missed if a standard linear partial adjustment model was used instead of the more flexible, non-linear, multivariate model. The linear partial adjustment model implies only that labor flexibility increases and capital flexibility decreases after the reforms and misses the asymmetries in labor and capital adjustments.

If factor reallocation facilitates the expansion of more efficient incumbents and the contraction of less efficient plants, then we may expect market reforms to be associated with productivity growth. We, thus, explore whether the changes in employment and capital adjustments after the Colombian reforms were productivity-enhancing and whether the hypothetical move to a completely frictionless world in factor markets would be productivity-enhancing. We find that moving towards frictionless factor adjustment would indeed increase productivity substantially (by more than 20 log points in any given year) by allowing the reallocation of activity from low towards high productivity plants. At the same time, we find that, while the reforms themselves seemed to have moved the economy towards an environment with less frictions in factor markets, productivity remains well below the frictionless levels after reforms. These results suggest that Colombian labor and capital adjustment are still subject to many restrictions that inhibit reallocation of resources and prevent the realization of all potential gains from productivity-enhancing reallocation. Although some of the remaining adjustment frictions may be the result of technological impediments (e.g. labor training or capital installation costs), other factor market frictions may be removed by deeper deregulation. In addition, we find that, even in the absence of frictions in labor and capital adjustments, allocative efficiency increased significantly after the reforms. The latter finding suggests that the reforms had an important impact on allocative efficiency above and beyond the impact of reducing capital and labor market adjustment frictions. In the Colombian context, the reforms appear to have reduced labor and capital market frictions only modestly, but the reforms did appear to improve allocative efficiency through channels other than the elimination of frictions on labor and capital adjustments.

While our results suggest that the reforms generated efficiency gains, it is also important to note that the much greater adjustment in response to labor surpluses after the reforms probably also generated important losses associated with worker displacement that would need to be quantified in order to assess the welfare effects of the reforms.

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Appendix

The first-order conditions for capital, employment, hours, energy and materials yield the following system of equations:

$$\bar{K}_{jt} = \frac{\frac{3}{-1} \bar{R}_t - \ln \bar{V}_{jt} - \frac{\mu}{h} \bar{E}_{jt} + \bar{H}_{jt} - \bar{E}_{jt} - \bar{M}_{jt}}{-1}, \quad (11)$$

$$\bar{E}_{jt} = \frac{\frac{3}{-1} \ln(1 + w_{1t} \bar{H}_{jt}) - \bar{V}_{jt} - \bar{K}_{jt} - \bar{H}_{jt} - \bar{E}_{jt} - \bar{M}_{jt}}{-1} \quad (12)$$

$$\bar{H}_{jt} = \frac{\frac{3}{-1} [w_{1t} - \bar{E}_{jt}] + \ln \bar{V}_{jt} - \bar{K}_{jt} - \bar{E}_{jt} - \bar{E}_{jt} - \bar{M}_{jt}}{-1} \quad (13)$$

$$\bar{E}_{jt} = \frac{\frac{3}{-1} \bar{P}_{Et} - \ln \bar{V}_{jt} - \bar{K}_{jt} - \frac{\mu}{h} \bar{E}_{jt} + \bar{H}_{jt} - \bar{M}_{jt}}{-1}, \quad (14)$$

$$\bar{M}_{jt} = \frac{\frac{3}{-1} \bar{P}_{Mt} - \ln \bar{V}_{jt} - \bar{K}_{jt} - \frac{\mu}{h} \bar{E}_{jt} + \bar{H}_{jt} - \bar{E}_{jt}}{-1}, \quad (15)$$

where \bar{E}_{jt} , \bar{K}_{jt} , \bar{H}_{jt} , \bar{E}_{jt} and \bar{M}_{jt} are the logs of E_{jt} , K_{jt} , H_{jt} , E_{jt} , and M_{jt} , respectively. Also, $\bar{V}_{jt} = \frac{1}{-1} \ln \frac{1}{-1} - \bar{D}_{jt}$ and $\bar{W}_{0t} = \frac{1}{-1} [w_{0t} - \ln \dots]$. Given our assumption of no adjustment costs for the use of hours, energy, and materials, \bar{H}_{jt} , \bar{E}_{jt} , and \bar{M}_{jt} are equal to their observed values. Therefore, the system is reduced to two equations and two unknowns: \bar{E}_{jt} and \bar{K}_{jt} . These equations, captured by (9), are expressed in terms of the parameters of the model, wages, interest rates, energy and materials prices, unobservable productivity and demand shocks, and the use of other factors: \bar{H}_{jt} , \bar{E}_{jt} , and \bar{M}_{jt} .

**Table 1: Output Weighted Descriptive Statistics,
Before and After Reforms**

Variable	Pre-Reforms	Post-Reforms
Output	14.33 (1.87)	15.08 (1.86)
Employment	5.64 (1.37)	5.65 (1.30)
Capital	12.04 (2.27)	12.66 (2.20)
Energy Consumption	15.03 (2.38)	15.13 (2.21)
Materials Use	13.44 (2.01)	13.87 (1.87)
Output Prices	-0.18 (0.45)	-0.66 (0.94)
Material Prices	0.04 (0.33)	-0.13 (0.48)
Energy Prices	0.20 (0.96)	0.33 (0.90)
Wages	251.55 (87.10)	298.63 (100.58)
TFP	1.56 (0.71)	1.98 (1.13)
Demand Shocks	6.10 (0.87)	5.95 (1.01)
Labor Shortage	0.15 (0.67)	0.06 (0.64)
Capital Shortage	0.34 (0.72)	-0.02 (0.73)
N	36,999	33,300

Notes: This table reports means and standard deviations of the log of quantities and of prices deviated from yearly producer price indices, as well as means and deviations of yearly wages in thousands of pesos of 1982. It also reports the first two moments of labor and capital shortages estimated using equations (1) and (2). All statistics are weighted by output. The pre-reform period includes the years 1982-1990, while the post-reform period includes the years 1991-1998.

**Table 2: Labor and Capital Adjustment Functions
Weighted by Employment and Capital, Respectively**

	Labor Adjustment				Capital Adjustment			
	(1) PAM	(2) PAM/ POSREF	(3) NLAM	(4) NLAM/ POSREF	(5) PAM	(6) PAM/ POSREF	(7) NLAM	(8) NLAM/ POSREF
Constant	0.1803 (0.0020)	0.1582 (0.0026)	0.1673 (0.0055)	0.1467 (0.0071)	0.2175 (0.0023)	0.2647 (0.0034)	-0.0355 (0.0063)	0.1414 (0.0110)
Pos. Shortage			-0.0297 (0.0091)	0.0028 (0.0108)			0.2439 (0.0107)	0.0283 (0.0148)
L Shortage ²			-0.0067 (0.0027)	-0.0075 (0.0036)			-0.0270 (0.0037)	-0.0464 (0.0083)
L Shortage ² × Pos. Shortage			0.0845 (0.0044)	0.0544 (0.0057)			0.1115 (0.0057)	0.1205 (0.0097)
K Shortage ²			-0.0049 (0.0025)	-0.0004 (0.0036)			0.1121 (0.0026)	0.0634 (0.0058)
K Shortage ² × Pos. Shortage			0.0348 (0.0042)	0.0149 (0.0062)			-0.0379 (0.0043)	0.0386 (0.0071)
L Shortage × K Shortage			-0.0058 (0.0026)	-0.0118 (0.0033)			-0.0693 (0.0033)	-0.1218 (0.0080)
L Shortage × K Sh. × Pos. Sh			-0.0664 (0.0048)	-0.0291 (0.0072)			-0.0169 (0.0052)	0.0571 (0.0093)
Post-reform		0.0430 (0.0032)		0.0381 (0.0079)		-0.0743 (0.0039)		-0.2206 (0.0111)
Pos. Shortage × Post-reform				-0.0584 (0.0112)				0.3538 (0.0148)
L Shortage ² × Post-reform				0.0037 (0.0045)				0.0219 (0.0089)
L Shortage ² × Pos. Sh. × Post				0.0475 (0.0066)				-0.0074 (0.0116)
K Shortage ² × Post-reform				-0.0089 (0.0051)				0.0649 (0.0058)
K Shortage ² × Pos. Sh. × Post				0.0303 (0.0082)				-0.1551 (0.0080)
L Shortage × K Sh. × Post				0.0047 (0.0051)				0.0575 (0.0084)
L Sh. × K Sh. × Pos. Sh. × Post				-0.0378 (0.0089)				-0.1633 (0.0114)
R squared	0.2238	0.2261	0.2358	0.2397	0.2410	0.2453	0.2972	0.3109
N	70,299	70,299	70,299	70,299	70,299	70,299	70,299	70,299

Notes: The table reports partial and non-linear adjustment functions estimated using equations (5) and (6), where estimation of the labor adjustment and capital adjustment functions weight observations by employment and capital, respectively. The labor shortage is estimated using equation (1) and the capital shortage using equation (2). The sample is a panel of pairwise continuing plants. The positive shortage dummy takes the value of 1 when there is a labor or capital shortage and the value of 0 when there is a labor or capital surplus. The post-reform dummy takes the value of 1 for plants observed during the years 1991-98 and the value of 0 for plants observed during the years 1983-90. Columns (1) and (5) show results for the Partial Adjustment Model. Columns (2) and (6) show results for the Partial Adjustment Model with coefficients that vary pre- and post-reform. Columns (3) and (7) exhibit the non-linear adjustment model. Finally, Columns (4) and (8) exhibit the non-linear model with coefficients that vary pre- and post-reform.

Table 3: Cross-Sectional Correlation Between Market Share and TFP
Counter-factual Output used to Calculate Market Shares

Year	Shares from projected output: both capital and labor adjustments vary post-reform (1)	Shares calculated with counter-factual output: only capital adjustment varies post-reform. (2)	Shares calculated with counter-factual output: only labor adjustment varies post-reform. (3)
1991	0.3740	0.3731	0.3798
1992	0.4489	0.4466	0.4609
1993	0.3821	0.3814	0.3845
1994	0.4394	0.4385	0.4416
1995	0.4957	0.4950	0.4980
1996	0.5916	0.5902	0.5938
1997	0.5589	0.5581	0.5613
1998	0.5522	0.5509	0.5564

Notes: All figures are simple means of 3-digit sector-level statistics. The sample has been restricted to plants for which counter-factual output can be calculated. Each column shows the contribution to aggregate productivity of the cross-sectional correlation between market share and TFP. Market share is the contribution of each plant to counter-factual output, calculated as in equation (12), of its 3-digit sector. Shares in Column (1) are obtained by allowing both capital and labor adjustments functions to change after reforms. Shares in Column (2) are obtained by allowing only the capital adjustment function to change after reforms. Shares in Column (3) are obtained by allowing only the labor adjustment function to change after reforms. Projected growth rates for factor demands, used in the calculation of counter-factual output, are truncated at -1.99 and 1.99.

Figure 1: Estimated Employment Adjustment Function and Distribution of Employment Shortages

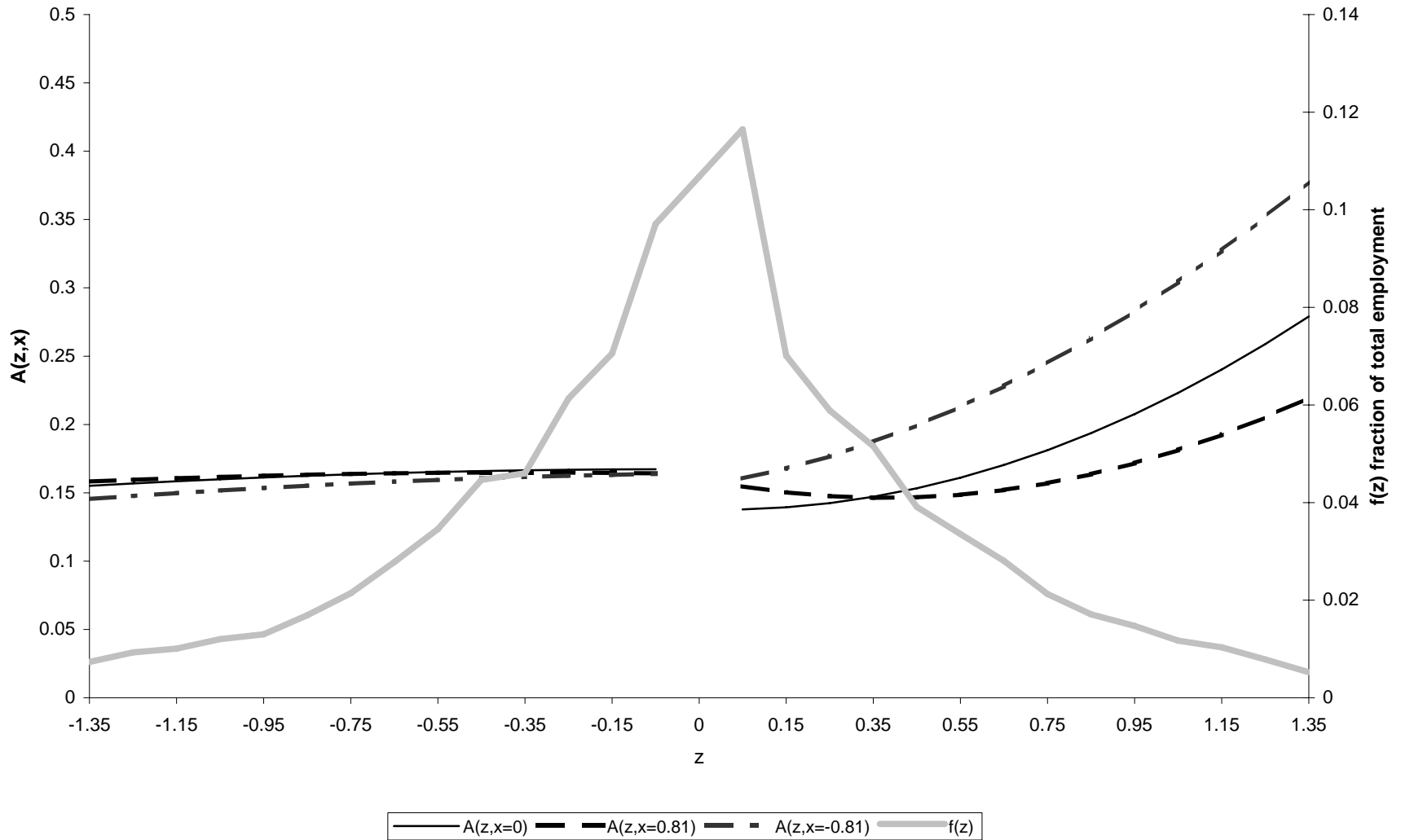


Figure 2.: Estimated Capital Adjustment Function and Distribution of Capital Shortages

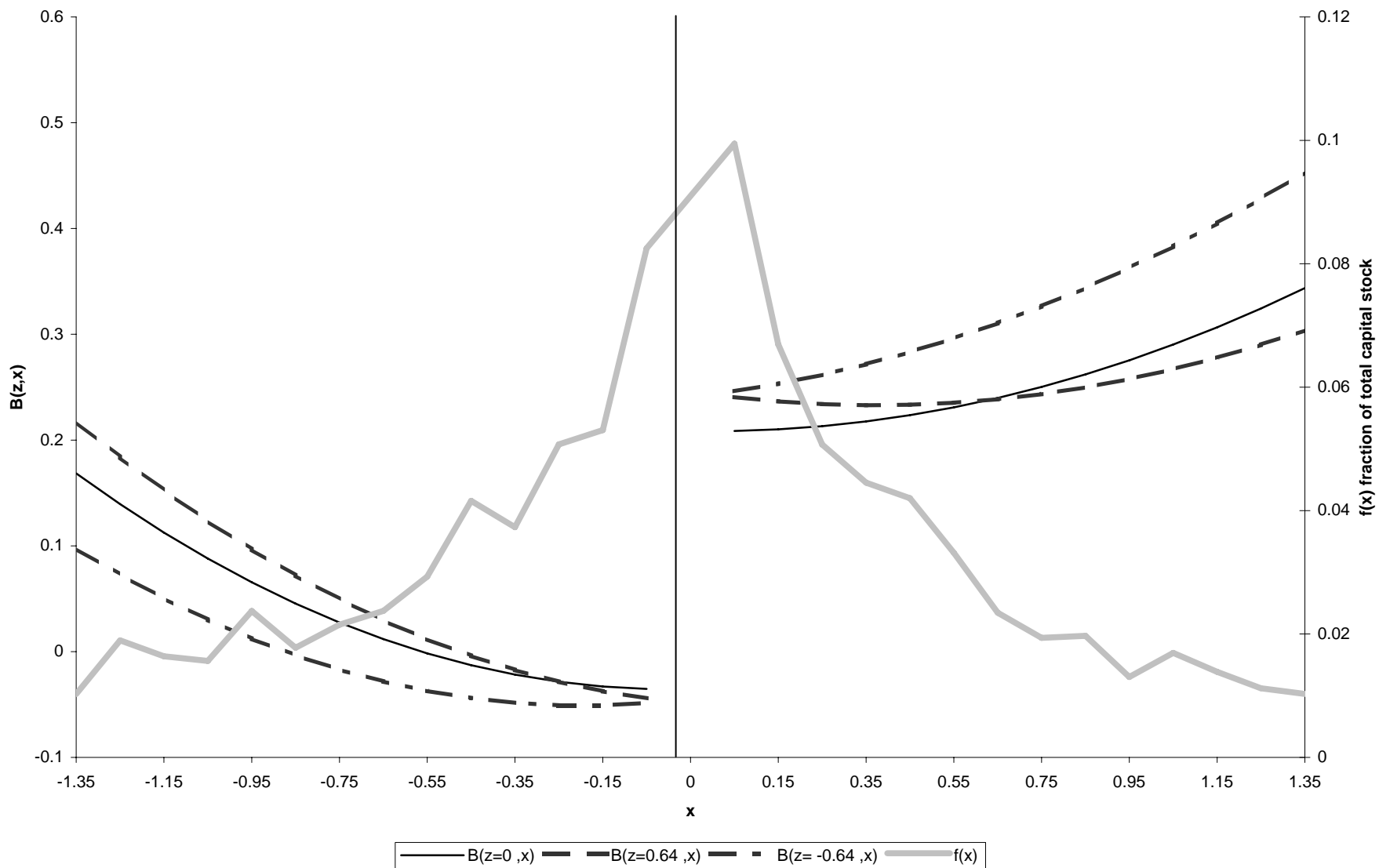


Figure 3.a.: Estimated Employment Adjustment Function and Distribution of Employment Shortages, Pre- and Post-Reform ($x=0$)

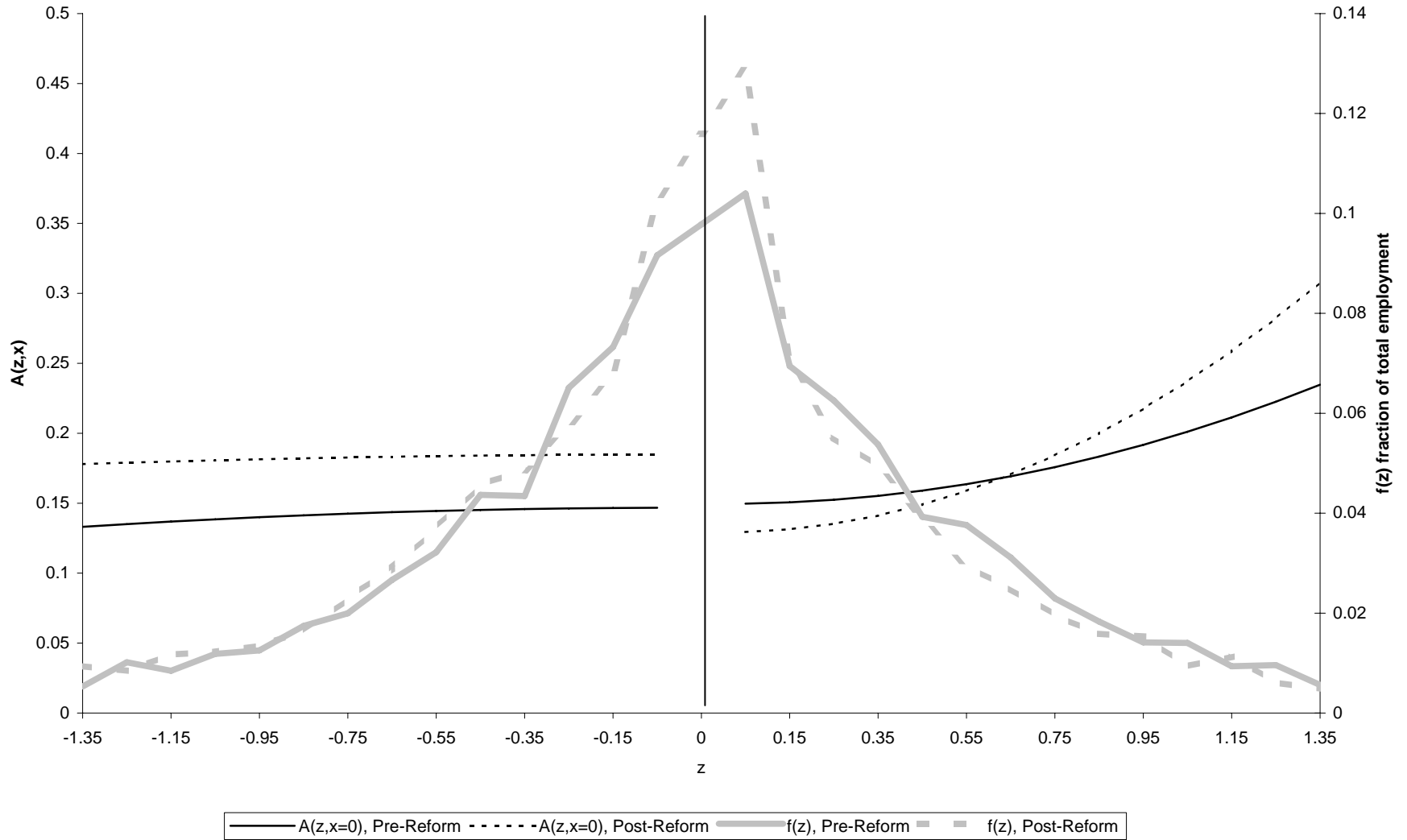


Figure 3.b.: Estimated Capital Adjustment Function and Distribution of Capital Shortages, Pre- and Post-Reform ($z=0$)

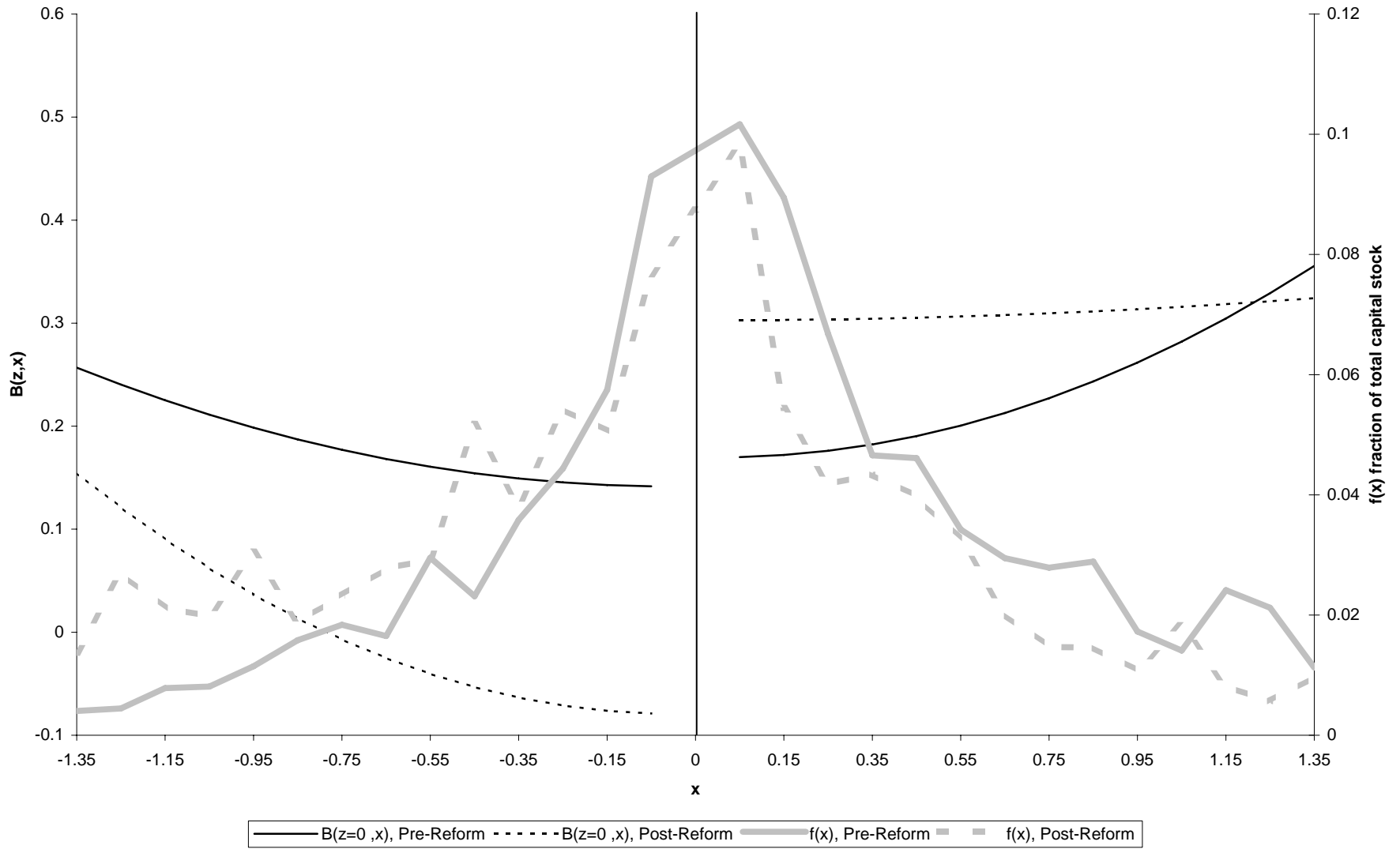
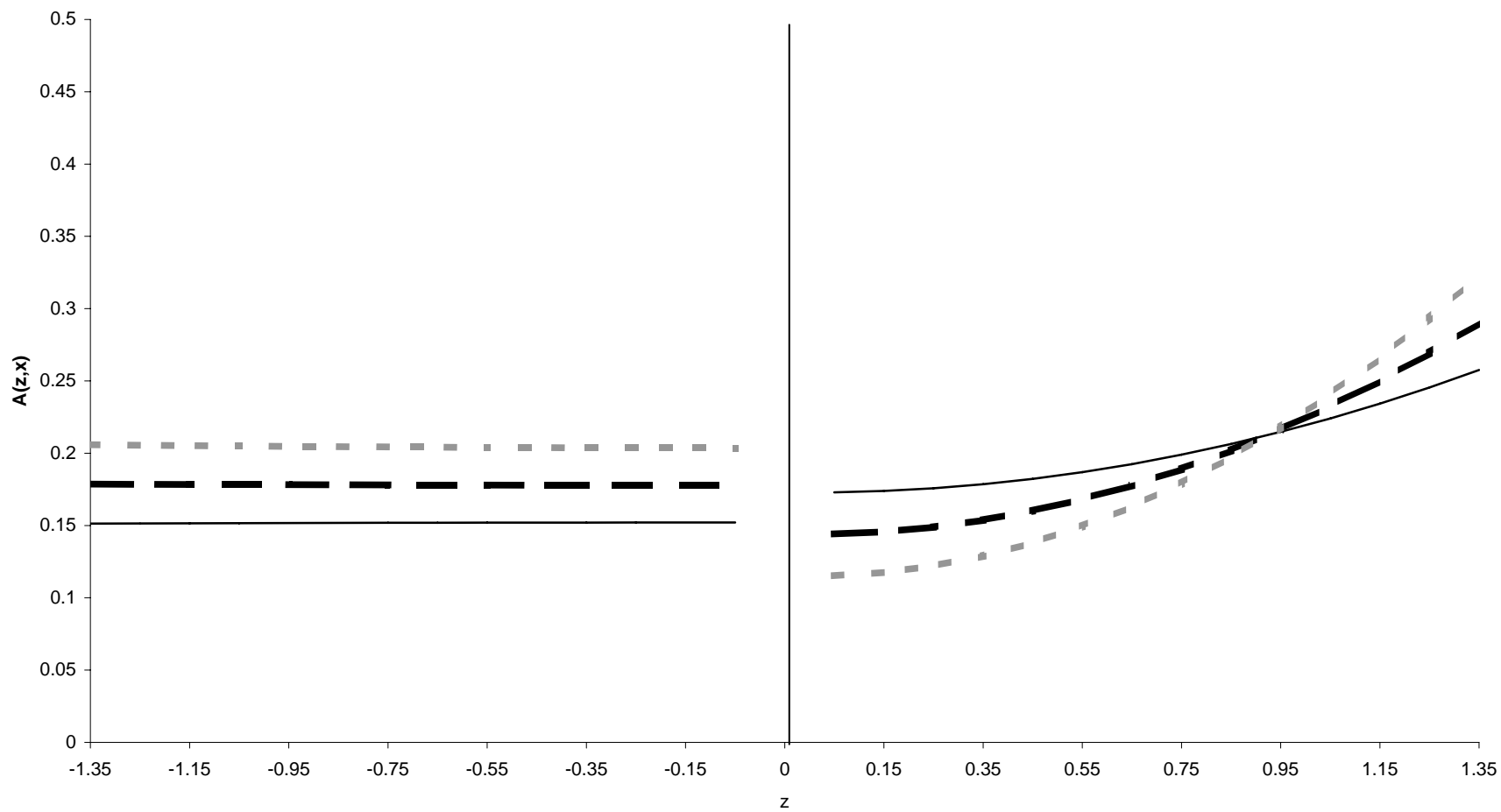


Figure 4.a.: Estimated Employment Adjustment Function at Different Levels of Reform Index ($x=0$)



— $A(z,x=0)$ RefIndex=0,3 - - - $A(z,x=0)$ RefIndex=0,5 - - - $A(z,x=0)$ RefIndex=0,7

Figure 4.b.: Estimated Capital Adjustment Function at Different Levels of Reform Index ($z=0$)

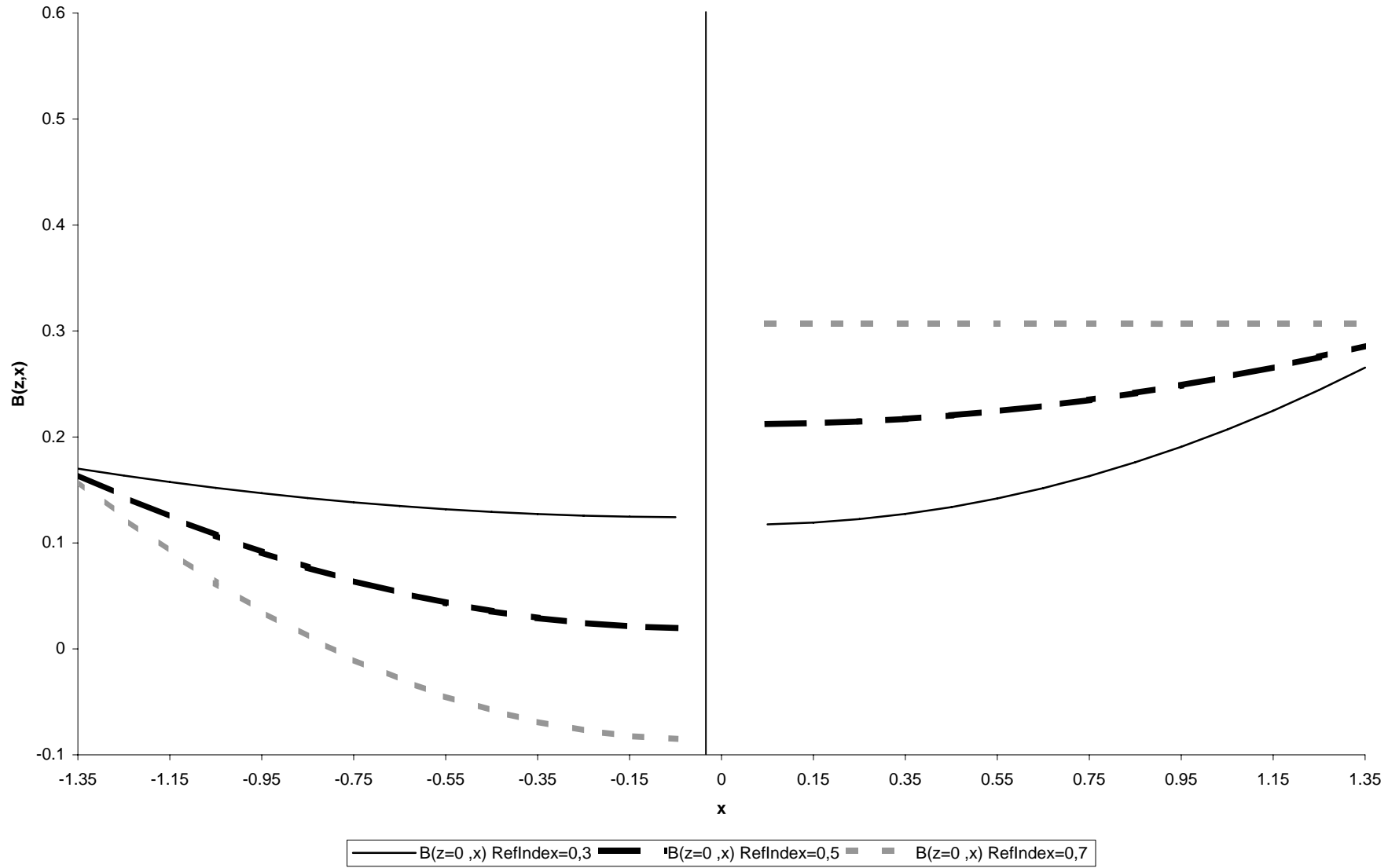


Figure 5: Re-scaled Reform Index for Colombia, 1985-1998

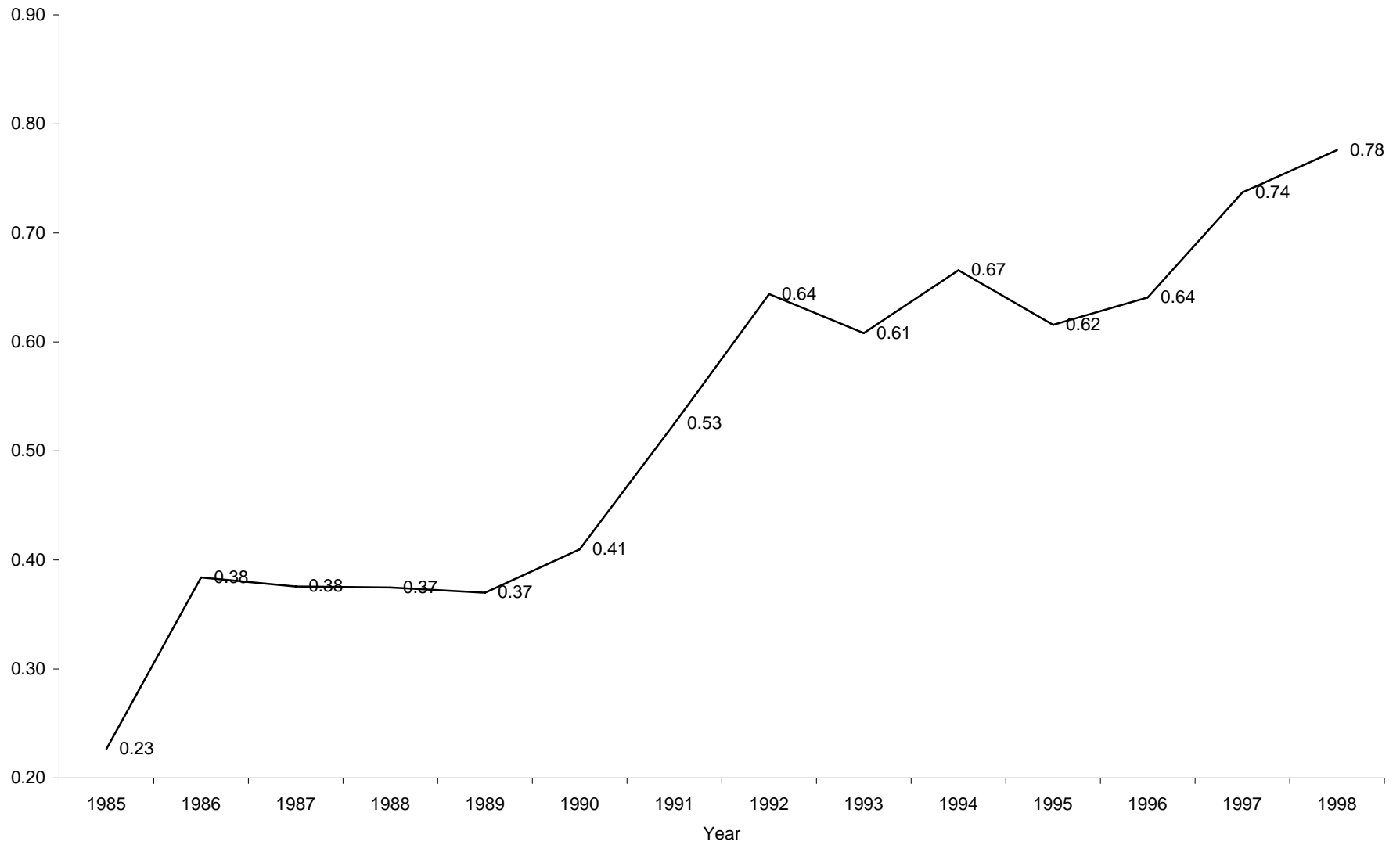


Figure 6: Aggregate TFP decomposition, simple average term and cross terms.

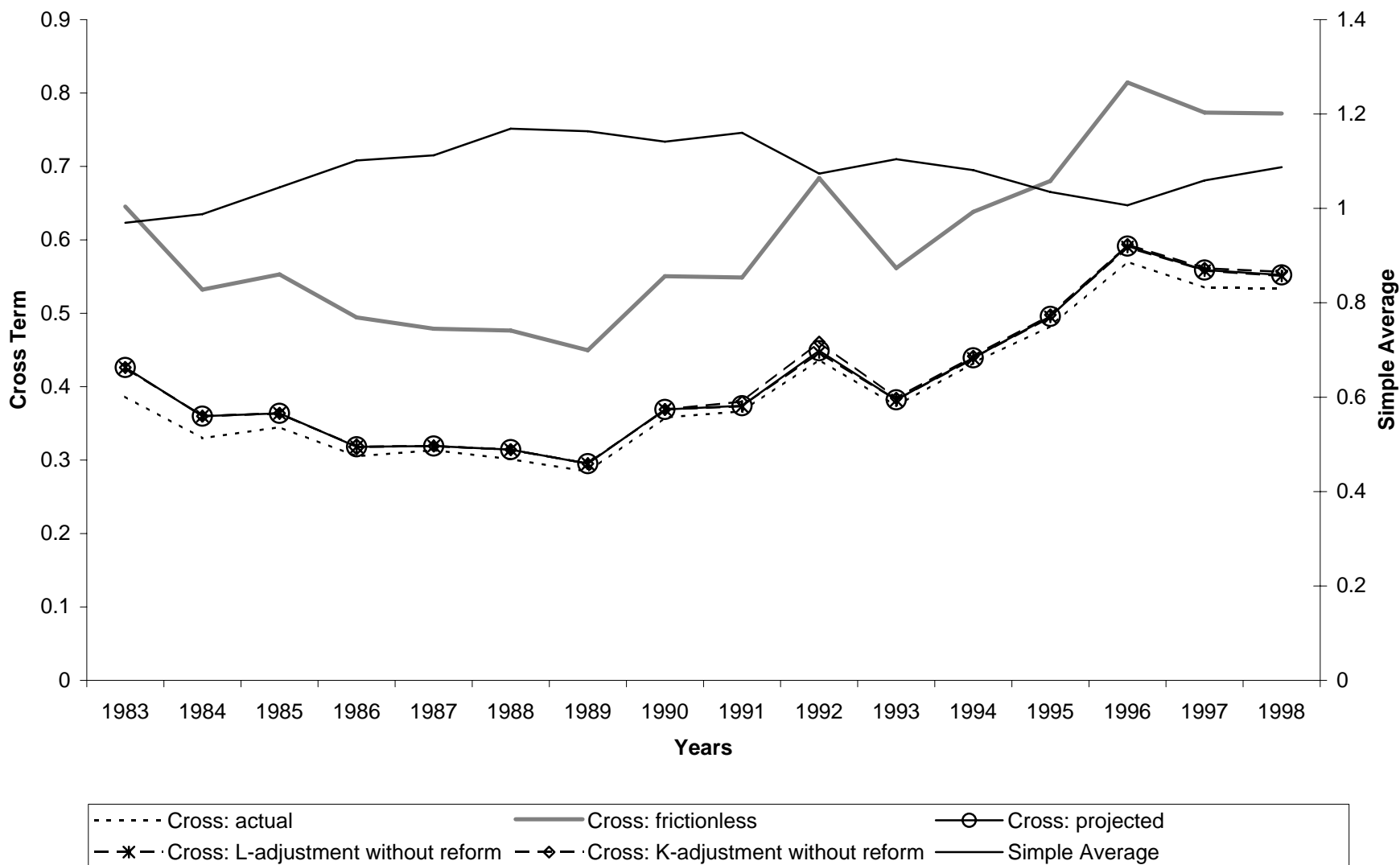


Figure A1: Estimated Employment Adjustment Function and Distribution of Employment Shortages

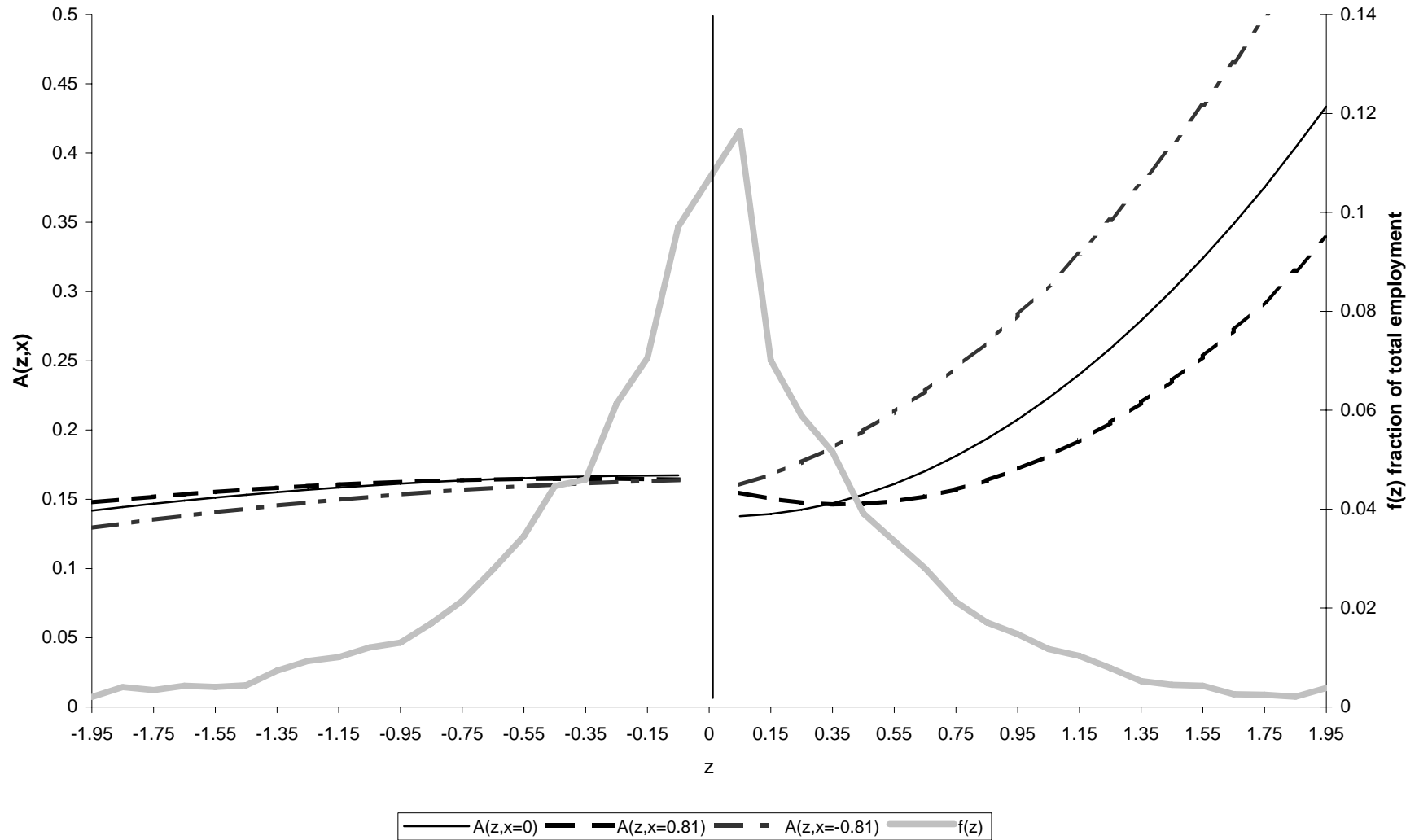


Figure A2: Estimated Capital Adjustment Function and Distribution of Capital Shortages

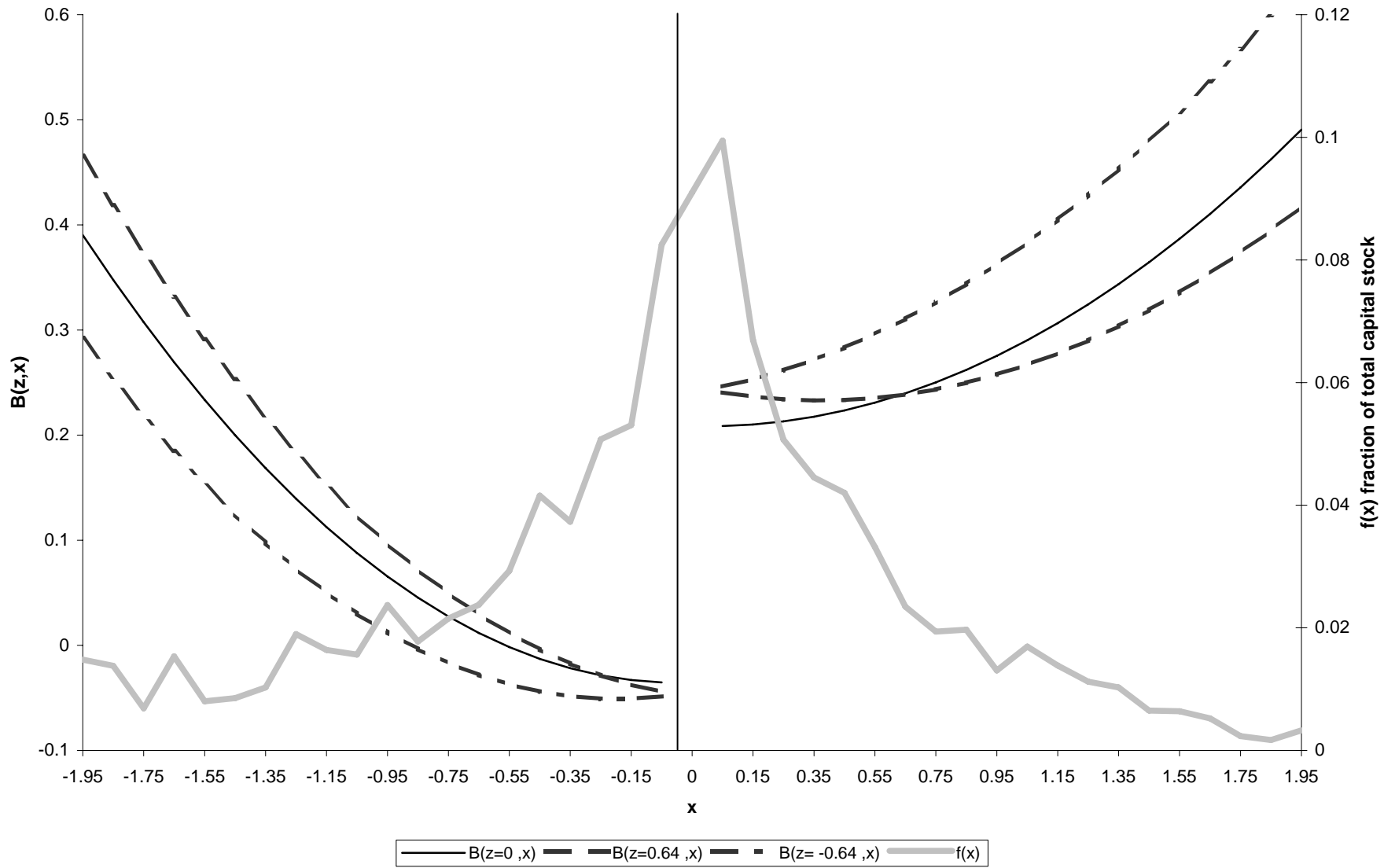


Figure A3.a.: Estimated Employment Adjustment Function and Distribution of Employment Shortages, Pre- and Post-Reform ($x=0$)

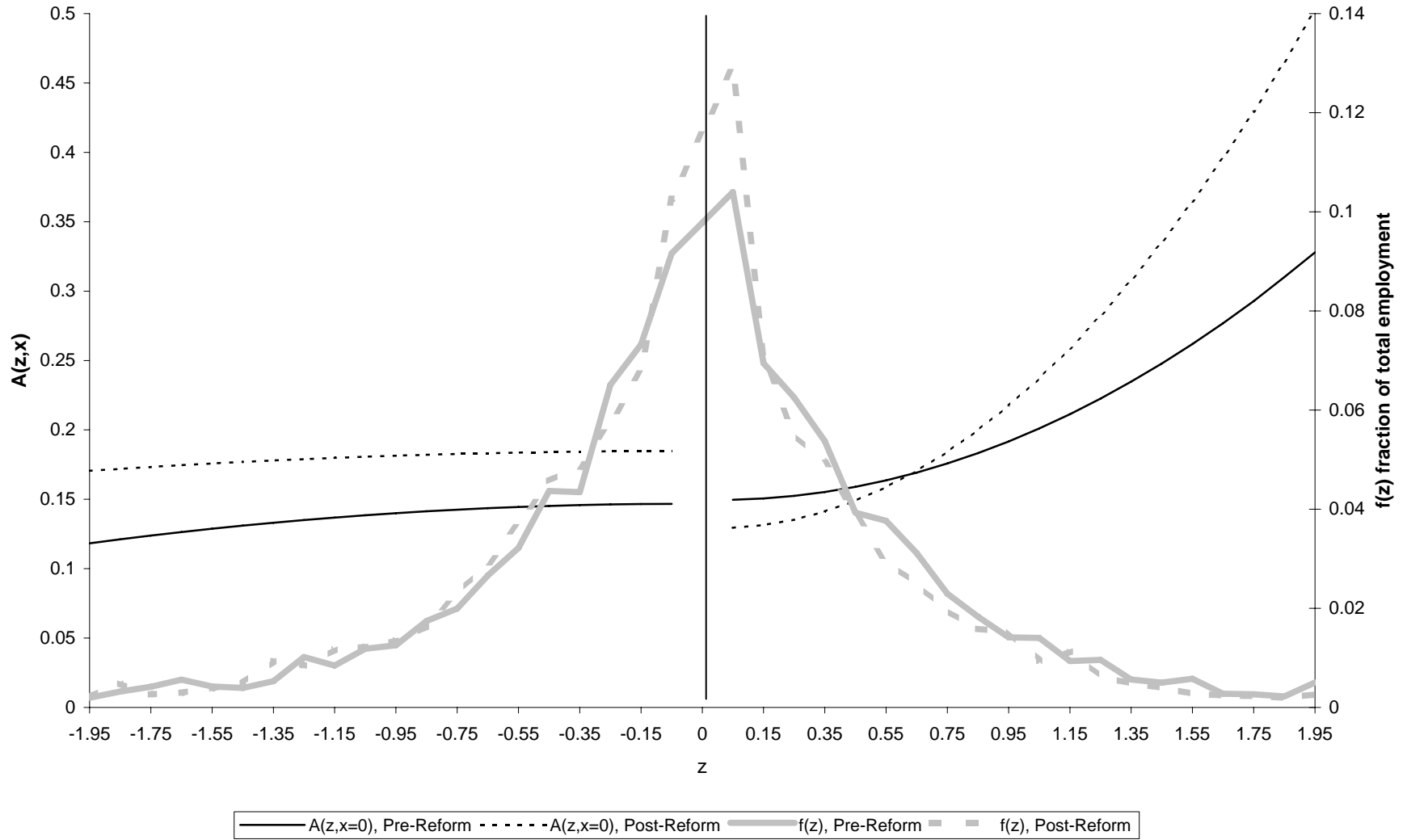


Figure A3.b.: Estimated Capital Adjustment Function and Distribution of Capital Shortages, Pre- and Post-Reform ($z=0$)

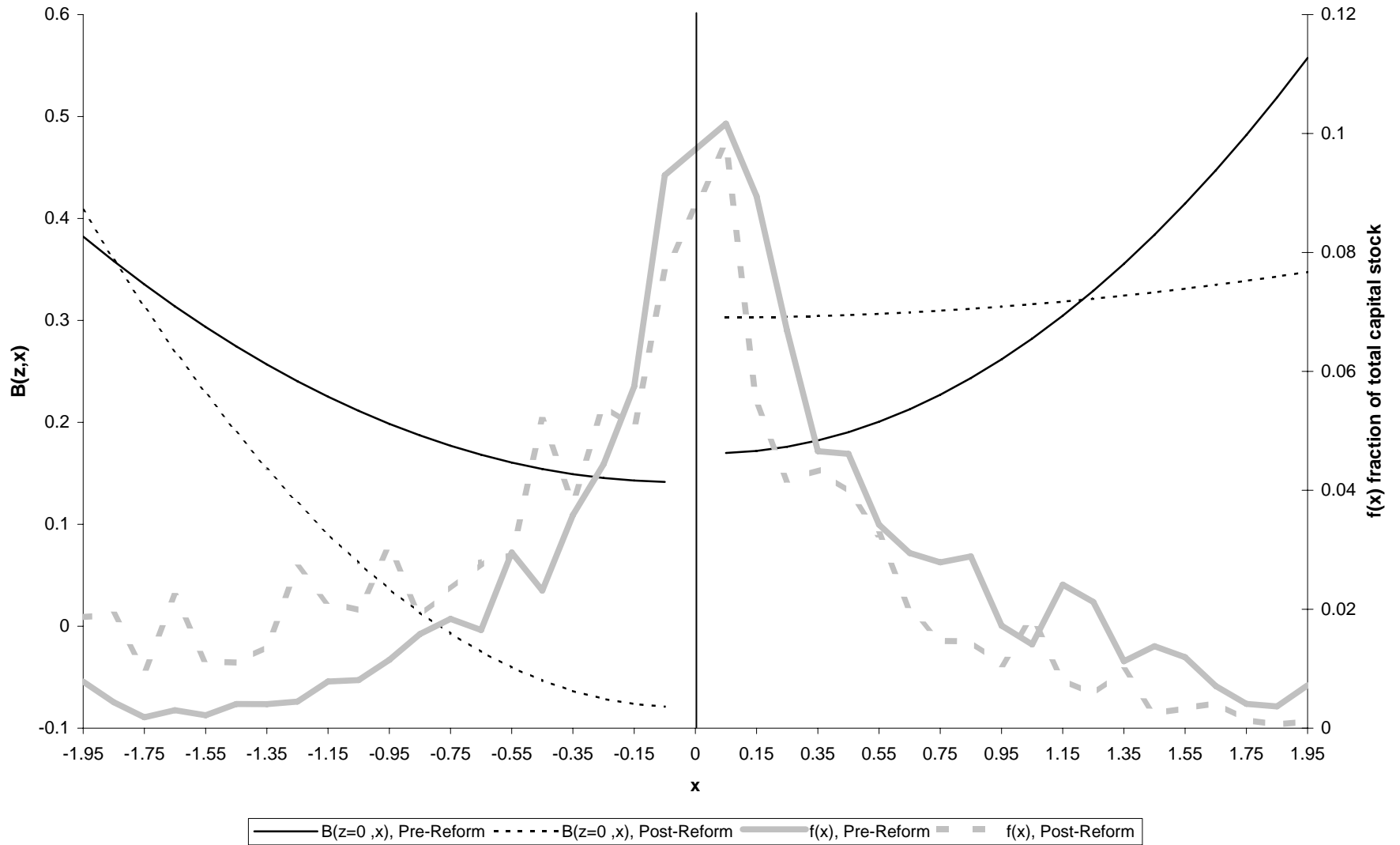
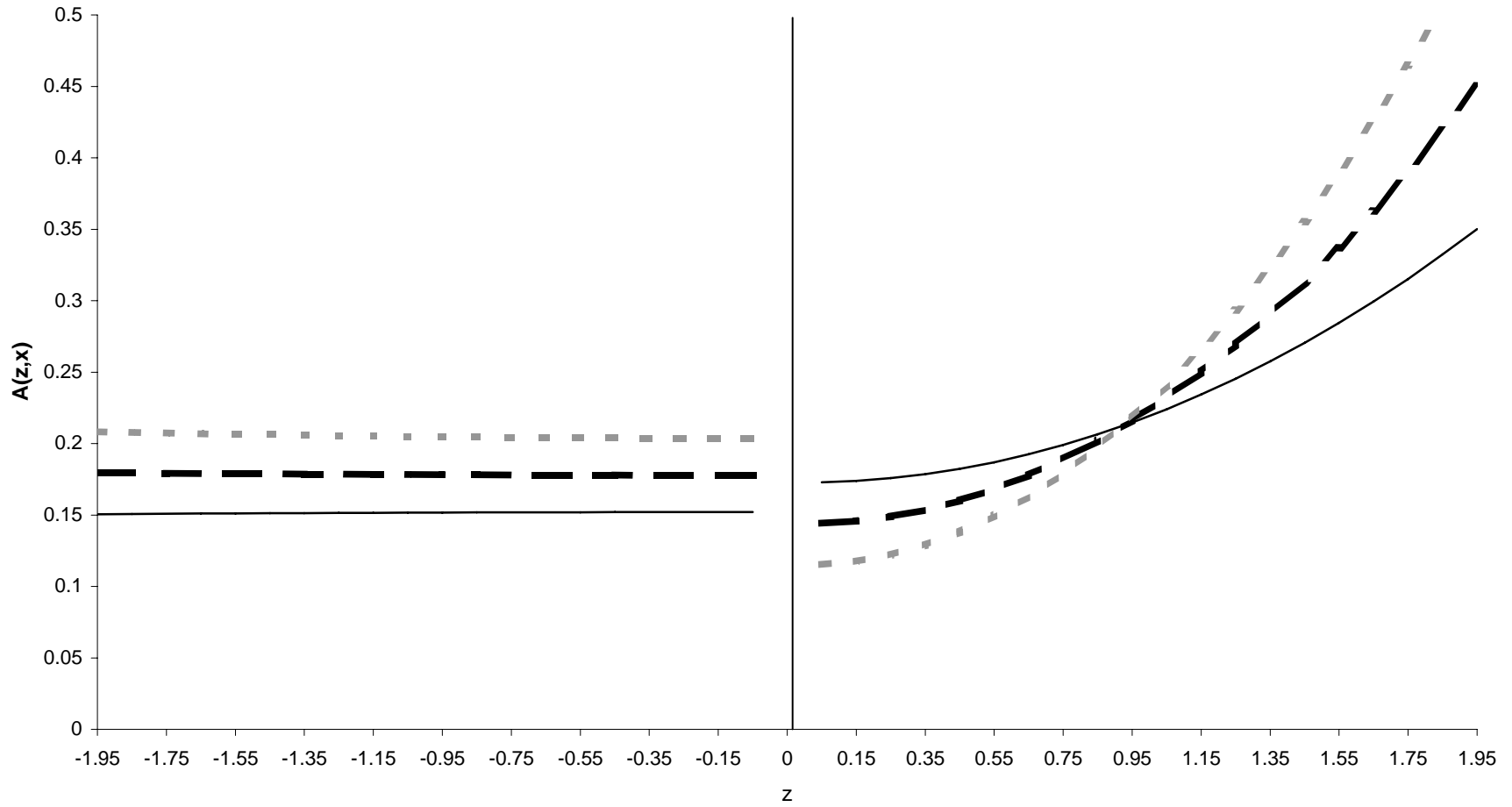
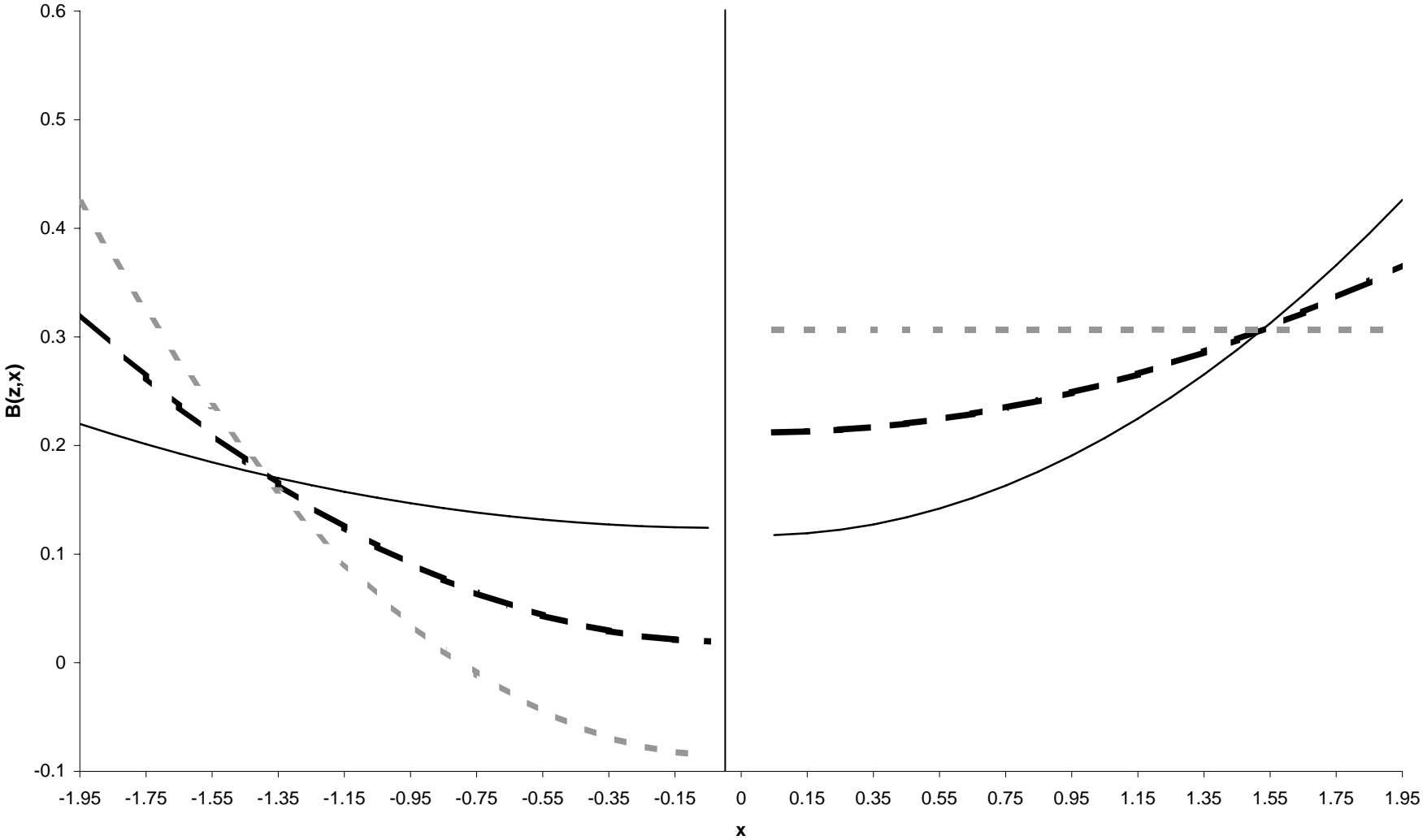


Figure A4.a.: Estimated Employment Adjustment Function at Different Levels of Reform Index ($x=0$)



— A(z,x=0) RefIndex=0,3 - - - A(z,x=0) RefIndex=0,5 - · - · - A(z,x=0) RefIndex=0,7

Figure A4.b.: Estimated Capital Adjustment Function at Different Levels of Reform Index (z=0)



— $B(z=0, x)$ RefIndex=0,3 - - - $B(z=0, x)$ RefIndex=0,5 - - - $B(z=0, x)$ RefIndex=0,7