Fixed Capital Adjustment: Is Latin America Different?

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We examine capital adjustment patterns using two large and largely novel plant-level data sets from the manufacturing sectors of Colombia and Mexico. The data suggest that irreversibilities play a larger role than in more advanced economies. However, we do not find support for the presence of increasing returns in the adjustment cost technology, such as arising from fixed costs. Firms go through periods of inaction, and rarely sell capital, but they do not invest at discrete times only. An examination of the dynamic patterns of adjustment of factors differing in their flexibility supports this interpretation.

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I. INTRODUCTION

In recent years, a growing literature on fixed investment has questioned the standard assumption that the cost of adjusting the capital stock can be represented by a strictly convex and continuously differentiable function of the size of the adjustment. This literature has shown that intuitively appealing extensions to this assumption, such as allowing the marginal cost of disinvestment to exceed the marginal cost of positive investment (i.e. allowing for at least partial irreversibilities) or adding a fixed adjustment cost, substantially alter the firm's optimal investment behavior. Both extensions lead to periods of inaction, while the second one (along with other cases of nonconvexities in the adjustment cost function) also yields infrequent episodes of large capital adjustments, i.e. investment bunching. [1] In either case, the usual representative firm model is, at least in a strict theoretical sense, no longer appropriate to describe aggregate investment.[2]

In order to assess empirically the nature of adjustment costs, macroeconomists have started to explore large microeconomic data sets. Recent studies by Doms and Dunne (1998), Cooper, Haltiwanger, and Power (1999) (henceforth CHP), and Caballero, Engel, and Haltiwanger (1995) provide evidence from the U.S. manufacturing sector that plant-level adjustments tend to occur at discrete times and that long spells of inactivity are followed by bursts in capital expenditures. These findings suggest the existence of indivisibilities, irreversibilities, and increasing returns in the adjustment cost function. Nilsen and Schiantarelli (1997) (NS) report similar findings for the Norwegian manufacturing sector, although their evidence for nonconvexities is weaker.

Beyond this pioneering work, the empirical documentation of capital adjustment patterns remains limited, and further examination of data from other countries is warranted to ascertain the general validity of the newer investment theories. Evidence from developing economies could be particularly insightful for this purpose. For example, because of the smaller size of the manufacturing sector in developing countries, secondary markets for used capital goods are likely to be thinner and investment irreversibilities consequently more important (Caballero, 1993). In addition, the macroeconomic environment in developing countries is characterized by large aggregate shocks and high volatility, and the revival of aggregate investment after macroeconomic adjustment in the 1980s turned out to be a slow endeavor (see e.g. Servén and Solimano, 1993). Therefore, it is useful to obtain a better picture of the patterns of microeconomic capital adjustments in these countries, both to test the general validity of the newer investment theories and as a first step toward a better understanding of aggregate investment behavior in developing economies.

This study examines the patterns of fixed capital adjustment at the microeconomic level in the manufacturing sectors of Colombia and Mexico, using two unique, large data sets. We find that, consistent with evidence from the U.S. and Norway, capital adjustments are characterized by periods of inaction, with rare downward adjustments. Similarly to CHP, we estimate hazard functions for the event that a firm experiences an investment spike. In contrast to their findings for the U.S. economy, these estimations for Mexico and Colombia do not provide evidence in favor of nonconvex adjustment costs. We conclude that irreversibilities, but not nonconvexities are the main characteristics of adjustment costs. A novel examination of the dynamic adjustment pattern of factors that differ in their degree of flexibility supports this interpretation.

II. Data

The data from Mexico are from the Annual Industrial Survey, conducted by the National Institute of Statistics, Geography, and Information (INEGI). The survey covers 3,199 manufacturing establishments from 1984-94. The panel is balanced: exiting plants were discarded from the sample by the collecting agency. However, according to INEGI, the number of exiting plants is small because the survey focuses on the largest firms, which are less likely to exit.

The data from Colombia are from the Annual Manufacturing Surveys for the period 1975-91. These surveys are conducted by the National Administrative Directorate of Statistics (DANE) and include all the manufacturing establishments that employ ten or more workers. They contain a core of mainly large or medium-sized plants that appear in every survey plus a much larger group of smaller plants entering and exiting the sample. In order to exploit as much as possible the information in the data while trying to make the results comparable with those for Mexico, we work with two samples for Colombia. The first one is a large unbalanced panel that comprises all the plants with at least five consecutive annual observations, and the second one is a balanced subpanel with all the plants appearing in each of the surveys between 1975 and 1991.

These unusually rich databases comprise a large number of variables about the plants' production, input use, labor force, sales, inventories, investment expenditures, and capital stocks. Data on capital expenditures are grouped into five categories: machinery, transport equipment, land, buildings, and other (office equipment in the Colombian case). This degree of disaggregation is particularly useful when investigating the nature of adjustment costs.

Investment is defined as purchases minus sales of assets plus improvements.[3] After the elimination of extreme outliers and plants with incomplete and inconsistent data, 2,575 establishments remain in the Mexican panel. For Colombia, the unbalanced panel contains 9,304 plants and the balanced subpanel contains 2,032 plants. Details of the construction of capital stocks and investment rates as well as for the criteria used for the elimination of outliers are given in the Appendix. The Colombian data include a much larger number of small establishments. For example, in the Mexican case, approximately 76 percent of all plants employ on average more than 50 people, whereas this is only true for approximately 54 percent of the plants in the Colombian balanced panel and only 26 percent of the establishments in the unbalanced panel.

III. The distribution Of Investment Rates

Table 1 provides information on the distribution of gross investment rates for different assets and the share of each interval in the total sum of positive investment of that category. Three intervals of positive investment are considered: maintenance investment ($0 < IR \leq d$, where d is the depreciation rate and IR is the investment rate); moderate investment ($d < IR \leq 0.2$); and high investment ($IR > 0.2$). For example, the entries in the fourth column and first row show that of all the recorded investment episodes in machinery equipment in Mexico, 12.1 percent were characterized by investment rates between 7 and 20 percent, accounting for 30 percent of total machinery investment in the sample.

Four main common features of the distributions are apparent. First, the frequency of negative investment episodes is very low in both countries. This is noteworthy, given the major structural changes that took place in Mexico and an important recession in Colombia during the periods covered. A possible explanation is the existence of some form of irreversibility that makes it costly for firms to sell capital goods. Alternatively, at least in the Mexican case the rare occurrence of negative investment could be the result of a bias towards expanding firms; however, the frequency of disinvestment does not differ between both samples for the case of equipment. Second, the share of zero investment episodes is very large, being highest in the case of real estate. Although there is probably an upward bias in these numbers, given that in some cases non-responses may have been registered as zeroes, this finding is similar to, but more extreme than, the ones reported for the U.S. (CHP) and Norway (NS). Larger plants are less likely to experience zero investment episodes: in the balanced Colombian subpanel, which covers larger plants, the frequency of zero investment episodes (not shown in the table) drops considerably (for example from 30% to less than 20% percent for equipment). [4] Third, similarly as found for the U.S. and Norway, a significant contribution to total investment comes from investment rates above 20 percent. Finally, a sizeable fraction of investment episodes can be characterized as maintenance investment, but its contribution to total capital expenditures is only modest. The relatively high frequency of small investment episodes suggests that fixed costs are not important for all types of capital adjustments.[5]

IV. THE DYNAMICS OF FACTOR ADJUSTMENT

Hazard function estimation

While the summary statistics presented above are indicative of the existence of irreversibilities, they are insufficient to assess whether the adjustment cost function is nonconvex. A more analytic approach is to examine whether the likelihood of an investment episode increases or decreases with the time elapsed since the last investment episode, by estimating a hazard function. This also allows for another comparison of the features of our data with those of U.S. and Norway.

The following discussion will be based on the predictions of a model developed by CHP. This framework allows for fixed costs of adjustment, a proportional cost component, and indivisibilities. Each period, firms can replace their existing machines by newer ones with leading technology and higher productivity. CHP present the solution to their dynamic programming problem in terms of a hazard function which depends on the firm's current capital stock and the aggregate state of productivity. Under fixed costs of adjustment and serially correlated profitability shocks, the probability of investment spike increases with the time elapsed since the last investment episode. On the other hand, if adjustment costs are convex, the hazard is flat or, with serially correlated profitability shocks, downward sloping.

In the spirit of CHP's model, we shall focus on spikes in equipment investment, which includes investment in machinery, transport equipment, and other capital (office equipment in the Colombian data). Two definitions of investment spikes will be used: a high spike is defined as an episode in which the investment rate exceeds 20 percent, while a low spike is an investment above the assumed depreciation rate of seven percent. Using the notation of NS, let t denote calendar time, and T_{ij} the time at which firm i has its j-th investment spike. The hazard rate can then be written as:

$$p_{ijt} = \Pr\left[T_{ij} = t | T_{ij} \geq t, t - \left(T_{ij-1} + 1\right), x_{it}\right], \tag{1}$$

where t-($T_{ij\text{-}1}$+1) is the interval since the last spike and the vector x_{it} represents additional variables. To model the hazard, various avenues can be taken. The Kaplan-Meier estimator calculates the probability of a spike conditional on the establishment not having experienced a spike over a period of a given length. It is computed by dividing the number of spikes in the sample by the number of firms "at risk" for every zero-spike period length. This estimator, however, has two shortcomings. First, it may be desirable to smooth the estimated hazard function by assuming an explicit functional form. More importantly, this specification does not control for unobserved heterogeneity. It is well known that in general, neglecting heterogeneity leads to downward-biased estimates of duration dependence (see, for example, Neumann, 1997). However, in the present setting, controlling for unobserved heterogeneity is not an easy task.[6]

Heckman and Singer (1984) propose including a random effect in the hazard, whose distribution is not parameterized, but instead assumed to be discrete with a limited number of mass points. We adopt this methodology for the estimation of a logit model with random effects.[7] Define D_{kit} as a dummy variable that takes a value of one if and only if the last investment spike was recorded k periods ago (k = 1,…,K), where $k \equiv t - T_{ij\text{-}1}$. When including time-specific effects l_t in the model, the conditional probability of an investment spike for plant i at time t given that the plant effect n_i equals n_m can be written as:

$$P_{itm} = P(S_{it} = 1 \mid n_i = n_m) = \frac{e^{\sum_{k=1}^{K} a_k D_{kit} + l_t + n_m}}{1 + e^{\sum_{k=1}^{K} a_k D_{kit} + l_t + n_m}}, \tag{2}$$

where S_{it} =1 if plant i experiences an investment spike at time t.

Treating the initial conditions as fixed, the log likelihood function is given by

$$\log L = \sum_{i=1}^{N} \log \sum_{m=1}^{M} pr_m \prod_{t=t_i}^{T} P_{itm}^{S_{it}} (1 - P_{itm})^{(1-S_{it})} , \tag{3}$$

where N is the number of plants, M is the number of mass points, pr_m are the associated probabilities, t_i is the year after plant i's first spike, and T is the last year of the panel. Note that this approach is not free from potential drawbacks. One issue, as in any maximum-likelihood estimation of dynamic models, concerns the treatment of initial conditions. Another complication may arise from a correlation between the time-invariant effects and the explanatory variables. The answer to these issues is not obvious, and the results should be interpreted with caution.

Tables 2A and 2B present results from the estimations of the simple Kaplan-Meier, simple logit, and logit with random effects estimations for equipment investment. We included completed spells and spells that were still ongoing in the last year of the sample.[8] For Colombia, we use the balanced subpanel. In most of the random-effects logit estimations, it turned out that allowing for two mass points was sufficient. The hazards estimated by the random-effect logit model (Equation 2) are depicted in Figures 1 and 2 for the different groups defined by the different mass points.

In general, the estimated hazards are downward-sloping, although there is some variation across countries, spike definitions, and estimation methods. Hazard functions based on the low spike definition tend to have a steeper slope, and the hazards for Colombia have lower slopes than the Mexican hazards. Moreover, the Colombian hazard based on the high spike definition is essentially flat after the first three periods. While the Mexican hazards exhibit an increase in the slope for the last duration analyzed (the seventh), their overall shape is more accurately described as downward-sloped than as U-shaped. The slopes of the hazards estimated as simple logits are slightly steeper than the those estimated as random effects logits, verifying the presumption that not accounting for heterogeneity introduces a downward bias in estimates of duration dependence.

In order to control for observed sources of heterogeneity we include additional covariates to the right hand side of Equation (2). Tables 2A and 2B show that including industry dummies, initial plant size (measured by its initial output), and the lagged sales/capital ratio did not substantially alter the shape of the hazards. The initial plant size was positive and significant, suggesting that larger plants are more likely to have an investment spike. The coefficient estimates for the lagged sales/capital ratio indicate that an investment spike is more likely for plants that have increased their sales the year before, particularly in Mexico. We also ran separate regressions for plants that exhibited slower and faster rates of growth during the sample period. The hazard for the fastest growing Colombian plants was the only one that showed an increase in its slope starting in the eighth year after a spike. However, the conditional probability of an investment spike ten years after a spike was clearly smaller than the conditional probabilities one and two years after a spike.

Financial constraints may yield downward-sloping hazards even in the presence of fixed costs. If investment must be financed internally, the ability of a firm to replace its machinery will depend on its cash-flow. Low productivity firms that need to replace their machinery may be unable to do so if replacement involves substantial fixed costs. As a result, their productivity is further reduced in the next period, making it even more difficult to undertake an investment. If productivity shocks are serially correlated, this behavior may induce a negative slope in the hazard function. Although the presumption that Mexican and Colombian plants are to a large degree financially constrained is supported by evidence presented elsewhere, an attempt to control for this possibility by including the cash flow at the firm level did not yield substantially different hazard shapes.[9]

Our results contrast sharply with CHP's results for the U.S. economy and are closer to those obtained by NS. Using the Heckman-Singer method with a proportional hazard specification, CHP obtain increasing hazard estimates, supporting the hypothesis of fixed adjustment costs. The hazard functions estimated by NS with random effects logit are depicted in Figure 3.[10] While the hazard they estimate using the high spike definition is basically flat, with an alternative spike definition based on the plant's median investment rate over the sample period, their hazard is U-shaped, first declining, and increasing only in the ninth and tenth years after a spike.[11] In sum, because none of our estimated hazard functions are upward-sloping, they do not support the hypothesis that the adjustment cost function has a fixed cost component.[12]

The dynamic adjustment of different types of capital goods

In order to investigate further the nature of fixed capital adjustment, we look at the adjustment of different types of capital goods around equipment investment spikes. The hazard function estimates indicate that in the periods following a spike, the probability of an investment spike continues to be high, i.e. that investment shows strong persistence. In Table 3 we compute average investment rates for equipment and land and buildings, along with growth rates of employment and sales, during and around high spikes in equipment investment. These tables indicate that the periods surrounding an investment spike are characterized by equipment investment rates that are lower than the typical investment spike, but significantly above the average. This suggests that the investments of these establishments *do not take place only at discrete intervals*. Rather, when plants engage in major investment projects, those are usually preceded and followed by smaller, and possibly complementary, expansions of capital.

The bunching of investment over various periods is fully consistent with the predictions of a model with convex adjustment costs and serially correlated productivity shocks, as shown in simulations by CHP. However, we saw earlier that plants went through periods of inaction and that negative investment rates were rare. We therefore believe that the evidence points to the presence of irreversibilities in the adjustment cost function, but not to increasing returns to scale, such as arising from fixed costs. Recall that the presence of partial irreversibilities creates a region of inaction.

After a series of positive productivity shocks moves the plant to the border of this range of inaction, it starts to invest. If the adjustment cost function has increasing returns, this investment takes the form of large spikes at discrete time intervals. Otherwise, investment is incremental, and with convex adjustment costs, it stretches over many periods. The latter behavior seems to correspond to the one observed here.

To be sure, the fact that investment episodes tend to stretch over many periods may be explained by alternative theories. For instance, the learning-by-investing model studied by Acemoglu and Scott (1997) could also lead to investment persistence. In that model plants face intertemporal rather than intratemporal increasing returns in investing, so that returns from investing this period are higher if an investment occurred in the recent past. Alternatively, the persistence in investment episodes might be explained by time-to-build considerations. Estimates for average completion times of investment projects in different industries range from three to eight quarters (see Liebermann, 1987, Koeva, 2000, and Mayer and Sonenblum, 1995). It is possible that some of the persistence observed in our data can be attributed to such phenomena.

The evidence on time-to-build is, however, mixed. The fact that spikes tend to be preceded and followed by smaller investments could be viewed as supporting a time-to-build interpretation. For example, if the completion time is two years and the plant starts a new project every year during three consecutive years, the resulting time path for the investment rate would have a peak at the year the three projects overlap, surrounded by other years of high investment. But if time-to-build were the main driving force behind the observed patterns, one should observe investment in assets with large time-to-build (such as structures) to show more smoothness than investment in other categories, which does not seem to be the case in our data.[13] Finally, the fact that employment growth drops much quicker when sales growth begins to decline while investment in equipment and structures remains rather high (see Table 3), is consistent with either a convex adjustment cost or a time-to-build interpretation.[14]

To provide further evidence for the presence of irreversibilities, we took a closer look at the dynamic behavior of different factors. Eberly and van Mieghem (1997) have expanded the standard model of irreversible investment to allow for more than one factor of production (see also Dixit, 1997, for the two-factor case). Production factors vary according to their degree of irreversibility, and factors whose resale price relative to their purchase price is low are said to be less flexible. The main predictions of the model are that (i) one should rarely see the less flexible factor adjusting if the more flexible one is not adjusted and (ii) adjustments in the less flexible factor are likely to be preceded by adjustments in the more flexible factors.

How can we examine whether these predictions hold in our samples? First, let us reformulate predictions (i) and (ii) in terms of conditional probabilities. Let i denote an index of factor flexibility such that higher values of i represent decreasingly flexible factors, and let A_{it} denote the event that factor i adjusted at time t, and A^C the complementary event. Prediction (i) can be stated more formally as $P(A_{it} \cap A_{ht}) > P(A_{it} \cap A_{ht}^C)$ for all $h < i$, which is identical to $P(A_{it})P(A_{ht}|A_{it}) > P(A_{it})P(A_{ht}^C|A_{it})$, or, more simply,

$$P(A_{ht}|A_{it}) > 0.5. \quad (4)$$

For example, if we observe an adjustment in buildings at time t we expect the probability of a contemporaneous adjustment in machinery (a more flexible factor) to be greater than 0.5.

Similarly, if we let p represent a period of time leading up to time t, prediction (ii) can be stated as $P(A_{it} \cap A_{hp}) > P(A_{it} \cap A_{hp}^C)$ for all $h < i$, which implies that

$$P(A_{hp}|A_{it}) > 0.5. \quad (5)$$

In words, the conditional probability of an adjustment in the more flexible factor during a period p preceding time t, given that one observes an adjustment in the less flexible factor at time t, is greater than 0.5. The theory is not explicit about how long the period p should be. In our analysis we consider p as the two-year period that includes the year of the adjustment in the less flexible factor and the year before that adjustment. For example, if we observe an adjustment in buildings in year *t*, we shall expect the probability that an adjustment in machinery occurred during the same year or during the year before to exceed 0.5.

In order to examine whether (4) and (5) hold in our samples, we examine the behavior of six factors. While we lack independent quantitative information on secondary market discounts, we believe that they can sensibly be ordered based on qualitative information about these countries, which tends to be consistent with the frequency of adjustments shown in Table 1. For example, while there are hiring and firing restrictions in both countries, they are quite easily circumvented in practice, so that labor can be regarded as a more flexible factor than fixed assets. Similarly, the market for non-specific office equipment such as computers can certainly be viewed as more liquid than that for specific machinery. While the market for certain specialized trucks may be limited, resale values for cars are typically high in Latin America. Structures employed by manufacturing plants are usually built for a specific purpose, which limits their resale value. Although there are well-organized markets for land, transaction costs (notaries, zoning restrictions, red tape, etc.) are quite high, suggesting that it is appropriate to characterize land as a very inflexible factor. Based on these considerations, we order the factors in the following way (in descending order of flexibility): labor, other/office equipment, transport equipment, machinery, buildings, and land. An adjustment is defined as an investment rate that exceeds the respective depreciation rate.[15]

The predictions of the theory are validated to a surprising extent: 51 out of the 60 sample conditional probabilities presented in the Tables 4A and 4B exceed 0.5. It is generally more likely that the adjustment of a less flexible factor occurs simultaneously with or is preceded by the adjustment of a more flexible factor than the other way around.[16] These results are consistent with the notion that irreversibilities play an important role in shaping capital adjustment patterns in both the Colombian and Mexican manufacturing sectors.

V. CONCLUDING REMARKS

Investment patterns in the Colombian and Mexican manufacturing sectors resemble each other and are in some respects similar to those found in the United States and Norway. Periods of inactivity are followed by investments that stretch over many periods. Plants sell fixed capital very rarely; instead, they reduce their capital stocks to lower desired levels by letting them depreciate. Irreversibilities appear to be even more important than in the United States. This finding is not surprising, given that secondary markets for capital goods are thinner in developing countries. On the other hand, we found evidence against the importance of nonconvexities, such as arising from fixed costs, in the adjustment technology. Therefore, the standard Ss model does not fit our data well. Instead, the investment behavior of the plants in our sample seems well described by a combination of partial irreversibility and a convex adjustment cost or time-to-build component.

The evidence on the importance of irreversibilities in the two countries analyzed suggests that it could be fruitful to move beyond the standard representative agent model of investment based on strictly convex and continuously differentiable adjustment costs for the study of aggregate investment in developing countries. Models that allow for the existence of an optimal range of inaction at the micro level and explicitly tackle the resulting aggregation problem are likely to help us improve predictions on the response of aggregate investment to economy-wide shocks. As mentioned earlier, the extent to which the representative firm model remains a good description of aggregate investment in developing countries is an empirical matter worthy of more research.[17]

A remaining question is why nonconvexities seem to be less important in Mexico, Colombia, and Norway than in the United States. While this may merely be a result of subtle differences in the datasets that are not easy to control for in independent studies, they may also reflect more fundamental differences in the economic environment in these countries. For example, differences in labor costs may yield differences in the cost of disruptions caused by the installation of new equipment. This is an issue for future investigation.

APPENDIX: CONSTRUCTION OF THE VARIABLES

Capital Stock: Both the Mexican and the Colombian surveys include replacement cost values for five categories of fixed assets: machinery equipment, buildings, land, transport equipment and other (office equipment for Colombia). We use a variant of the permanent inventory method to compute capital stocks. The usual perpetual inventory method starts from an initial value of capital (usually the book value of the first year) to construct all subsequent values. However, this method could potentially yield too low estimates, for example, if there is no proper adjustment for inflation. On the other hand, firms are often required to update their book values to the market value by law. Therefore, even if the initial book value is a poor proxy for the actual capital stock, chances are that at least some subsequent book values may be a better proxy for the capital stock at a later date. In order to exploit such information, and assuming that the book value at time *t* represents a lower bound for the actual capital stock (BV_t £ K_t " t), we improve upon the traditional perpetual inventory method with the following two-step procedure:

1) Letting I and S denote investment and sales, respectively, let $K^1_0 = BV_0$ and compute

$$K_t^1 = (1-d)\,Max\{K_{t-1}^1, BV_{t-1}\} + I_t - S_t \quad \text{for } t > 0$$

2) Set $K_T = K^1_T$ (where T is the last year in the sample) and compute

$$K_{t-1} = \frac{K_t^1 - I_t + S_t}{1-d} \text{ for } t \in [1, T]$$

The first recursion captures any possible update in the book value of capital during the sample period. The second recursion updates the values of the capital stock that preceded the update, so that the final series is consistent with the standard permanent inventory method while including a better estimate for the initial capital stock. Zero depreciation was assumed for land, a rate of 4 percent was chosen for buildings and 7 percent for all other asset categories.

Investment: Investment is defined as purchases minus sales of used and new assets plus improvements on existing assets plus capital assets produced for own use. For Mexico, machinery and transport equipment investment were deflated by the machinery price index, other investment by the wholesale price index, purchases of land by the mid-year Mexico City Land Price Index, and expenditures on construction by a construction price index. For Colombia, machinery and office equipment were deflated with the machinery price index, transportation equipment by the transportation price index, and construction and land investment by the construction price index. All price indices were obtained from Banco de México and Banco de la República.

Outliers: Establishments reporting investment rates less than -90 percent or larger than 200 percent for any subcategory of capital analyzed were dropped from the sample. In Table 1, we applied this criterion to each of the rows separately. In Tables 2A and 2B we applied it to equipment investment, and in Tables 3 and 4 we applied it simultaneously to equipment investment, investment in land and buildings, and the growth rates of employment and sales.

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Table 1. Mexico and Colombia: Distribution of Fixed Gross Investment Rates and Share in Total Investment by Category

Category	Disinvestment $\frac{I_{it}}{K_{it-1}} < 0$	Zero Investment $\frac{I_{it}}{K_{it-1}} = 0$	Maintenance Investment $0 < \frac{I_{it}}{K_{it-1}} \leq d$ [1]	Moderate Investment $d < \frac{I_{it}}{K_{it-1}} \leq 0.2$	High Investment $\frac{I_{it}}{K_{it-1}} > 0.2$
MEXICO					
1) Machinery	3.2 %	39.0 %	35.4 % (30.6 %) [2]	12.1 % (30.0 %)	10.3 % (39.4 %)
2) Transport	8.9 %	43.5 %	15.0 % (14.4 %)	15.0 % (30.9 %)	17.6 % (54.7 %)
3) Other	2.4 %	43.0 %	22.7 % (10.3 %)	16.6 % (22.3 %)	15.3 % (67.4 %)
4) Equipment (1+2+3)	4.3 %	28.4 %	38.8 % (29.2 %)	17.4 % (32. 0 %)	11.1 % (38.8 %)
5) Buildings	1.9 %	65.7 %	21.4 % (29.4 %)	5.9 % (27.9 %)	5.0 % (42.7 %)
6) Land	1.9 %	94.8 %	-	2.5 % (35.5 %)	1.2 % (64.5 %)
COLOMBIA					
1) Machinery	4.5%	39.2%	22.2% (11.6%)	15.0% (29.1%)	19.0% (59.3%)
2) Transport	7.6%	62.1%	6.2% (10.0%)	7.6% (25.8%)	16.6% (64.1%)
3) Other	2.9%	46.0%	15.1% (6.5%)	15.3% (27.6%)	20.7% (65.9%)
4) Equipment (1+2+3)	5.7%	30.4%	24.6% (11.4%)	18.2% (32.2%)	21.1% (56.3%)
5) Buildings	4.2%	67.2%	10.0% (6.3%)	9.7% (36.0%)	8.9% (57.7%)
6) Land	5.3%	84.7%	-	5.6% (29.9%)	4.5% (70.1%)

[1] The depreciation rate *d* is 0.07 for items 1 to 4, 0.04 for buildings, and 0 for land.
[2] Shares in total positive investment are shown in parentheses.

Table 2A. Mexico: Hazard Estimates for Equipment Investment

Variable	Kaplan-Meier High Spike	Kaplan-Meier Low Spike	Logit High Spike	Logit Low Spike	Random Effects Logit High Spike		Random Effect Logit Low Spike	
D1	0.28	0.52	1.73	2.16	1.30	1.36	1.43	1.44
	(41.61)	(99.61)	(10.01)	(15.03)	(7.37)	(7.70)	(9.77)	(9.75)
D2	0.16	0.31	1.21	1.38	0.84	0.89	0.82	0.84
	(20.10)	(40.09)	(6.86)	(9.42)	(4.68)	(4.91)	(5.53)	(5.57)
D3	0.13	0.25	0.92	1.03	0.59	0.61	0.62	0.62
	(13.80)	(24.97)	(4.99)	(6.86)	(3.18)	(3.27)	(4.05)	(4.01)
D4	0.12	0.18	0.77	0.54	0.50	0.50	0.23	0.23
	(11.37)	(14.22)	(4.05)	(3.40)	(2.61)	(2.60)	(1.42)	(1.42)
D5	0.10	0.14	0.45	0.22	0.24	0.22	-0.02	-0.03
	(7.96)	(9.24)	(2.23)	(1.27)	(1.15)	(1.05)	(-0.10)	(-0.16)
D6	0.09	0.10	0.34	-0.06	0.18	0.16	-0.23	-0.21
	(6.45)	(6.04)	(1.58)	(-0.34)	(0.81)	(0.73)	(-1.21)	(-1.07)
D7	0.11	0.12	0.61	0.20	0.52	0.53	0.10	0.13
	(6.90)	(6.03)	(2.86)	(1.01)	(2.37)	(2.42)	(0.51)	(0.66)
Initial Q	-	-	-	-	-	0.05	-	0.09
						(3.13)		(9.08)
Lagged Sales/K	-	-	-	-	-	0.05	-	0.05
						(12.00)		(14.70)
Const 1	-	-	-2.00	-1.58	-1.17	-2.3514	-0.07	-0.8428
[probability]			[1.00]	[1.00]	[0.62]	[0.91]	[0.37]	[0.38]
Const 2	-	-	-	-	-2.43	-21.2962	-1.34	-1.964
[probability]					[0.38]	[0.09]	[0.63]	[0.62]
Year Dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Sector Dummies	No	No	No	No	No	Yes	No	Yes
F-test	372.48	1787.65	-	-	-		-	
	(7,10512)	(7,17026)						
c^2	-	-	530.2	2145.4	-		-	
			(16)	(16)				
# of observ.	10519	17033	10519	17033	10519	10500	17033	16997

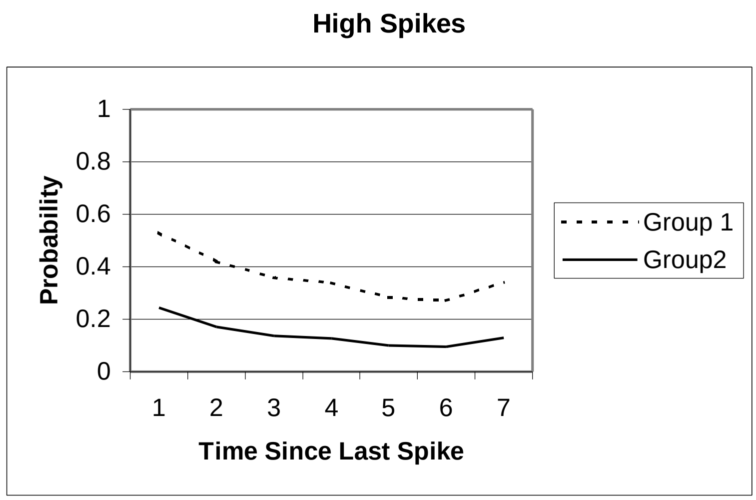
The dependent variable is the probability that plant *i* experiences an investment spike at time *t*. t-statistics in parentheses.

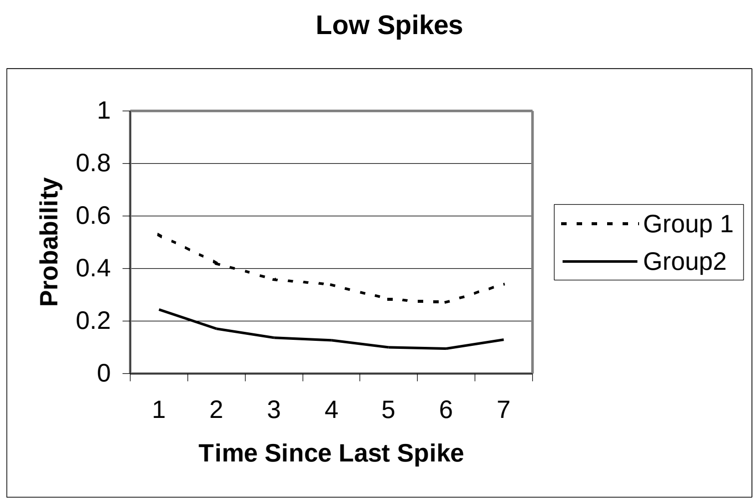
Table 2B. Colombia: Hazard Estimates for Equipment Investment

Variable	Kaplan-Meier High Spike	Kaplan-Meier Low Spike	Logit High Spike	Logit Low Spike	Random Effects Logit High Spike		Random Effects Logit Low Spike	
D1	0.31	0.59	1.20	2.32	0.96	0.97	1.57	1.46
	(64.19)	(146.40)	(10.04)	(14.31)	(8.00)	(8.04)	(9.62)	(8.90)
D2	0.24	0.43	0.94	1.71	0.75	0.75	1.15	1.05
	(40.67)	(66.04)	(7.76)	(10.49)	(6.12)	(6.13)	(6.97)	(6.32)
D3	0.20	0.35	0.80	1.46	0.64	0.64	1.03	0.92
	(28.50)	(39.91)	(6.51)	(8.83)	(5.17)	(5.17)	(6.16)	(5.51)
D4	0.15	0.27	0.60	1.11	0.47	0.46	0.77	0.67
	(18.96)	(23.52)	(4.71)	(6.54)	(3.61)	(3.59)	(4.52)	(3.91)
D5	0.15	0.23	0.67	0.88	0.55	0.55	0.62	0.52
	(16.74)	(16.23)	(5.08)	(5.03)	(4.19)	(4.15)	(3.52)	(2.94)
D6	0.13	0.21	0.49	0.81	0.39	0.39	0.63	0.53
	(12.30)	(12.81)	(3.56)	(4.44)	(2.84)	(2.82)	(3.43)	(2.89)
D7	0.12	0.18	0.48	0.62	0.40	0.39	0.48	0.39
	(10.78)	(9.28)	(3.34)	(3.22)	(2.78)	(2.76)	(2.51)	(2.03)
D8	0.12	0.19	0.44	0.73	0.38	0.37	0.64	0.55
	(9.20)	(8.71)	(2.96)	(3.65)	(2.54)	(2.48)	(3.22)	(2.76)
D9	0.11	0.17	0.34	0.54	0.30	0.29	0.49	0.43
	(7.46)	(6.28)	(2.13)	(2.44)	(1.85)	(1.79)	(2.22)	(1.92)
D10	0.11	0.13	0.42	0.27	0.39	0.39	0.24	0.19
	(6.83)	(4.09)	(2.42)	(1.03)	(2.25)	(2.23)	(0.91)	(0.71)
Initial Q	-	-	-	-	-	0.06	-	0.19
						(5.98)		(22.59)
Lagged Sales/K	-	-	-	-	-	0.01	-	0.00
						(4.23)		(1.74)
Const 1	-	-	-1.77	-1.80	-1.53	-2.15	-0.40	-2.22
[probability]			[1.00]	[1.00]	[0.74]	[0.80]	[0.41]	[0.44]
Const 2	-	-	-	-	-1.96	-2.59	-1.59	-3.24
[probability]					[0.18]	[0.18]	[0.59]	[0.56]
Const 3	-	-	-	-	-0.72	-1.51	-	
[probability]					[0.08]	[0.02]		
Year Dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Sector Dummies	No	No	No	No	No	Yes	No	Yes
F-test	768.1	2858.6	-	-	-		-	
	(10,24844)	(10,28084)						
c^2	-	-	1512.3	3168.7	-		-	
			(25)	(25)				
# of observ.	24854	28094	24854	28094	24854		28094	

The dependent variable is the probability that plant *i* experiences an investment spike at time *t*. t-statistics in parentheses.

Figure 1. Mexico: Hazard Estimates for Equipment Investment (Random Effects Logit Estimation)

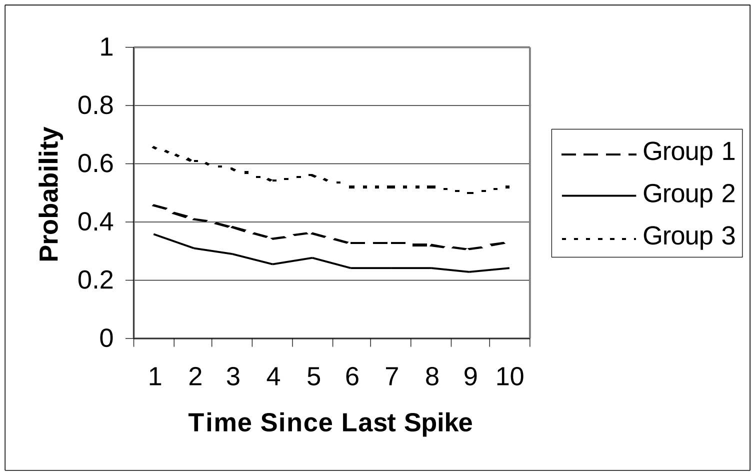




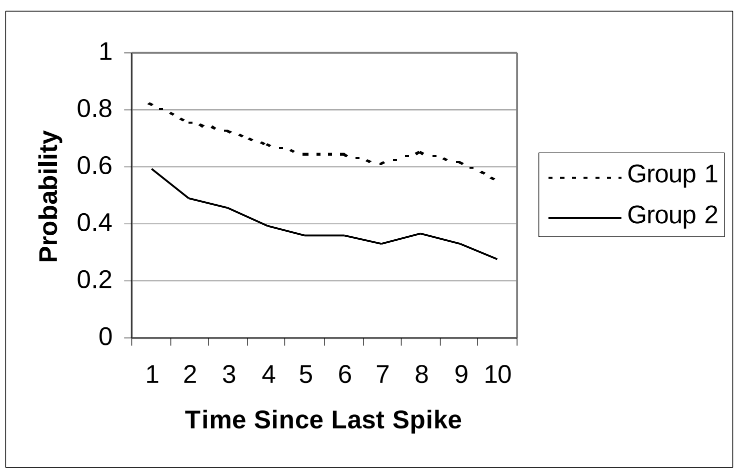
Source: Authors' calculation based on data from INEGI. Probabilities were calculated for the year 1985.

Figure 2. Colombia: Hazard Estimates for Equipment Investment (Random Effects Logit Estimation)

High Spikes

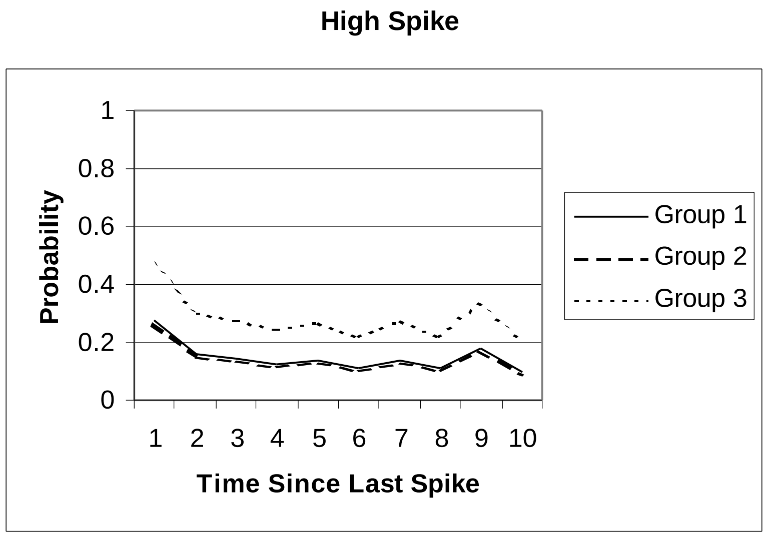


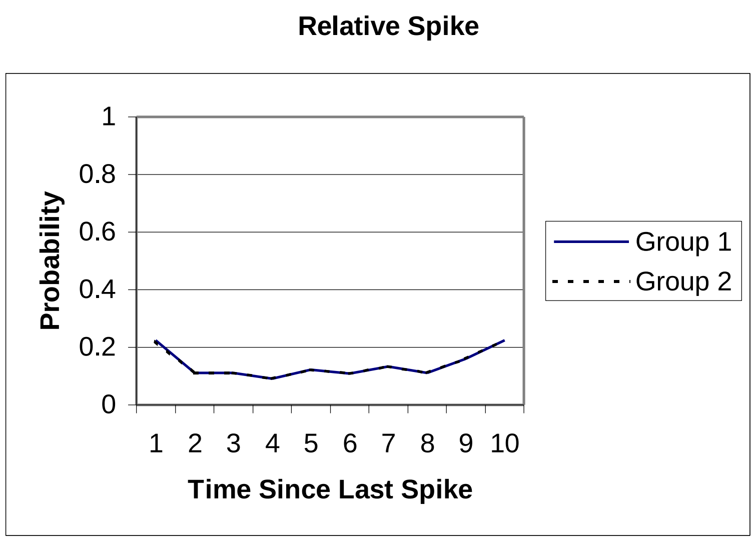
Low Spikes



Source: Authors' calculation based on data from DANE. Probabilities were calculated for the year 1978.

Figure 3. Norway: Hazard for Equipment Investment (Nilsen and Schiantarelli 1997)





Source: Authors' calculation based on data from Nilsen and Schiantarelli (1997, Table 6A).

Table 3. Mean Investment Rates and Change in Employment and Sales
At and Around High Spikes of Equipment Investment

	t-2	t-1	t	t+1	t+2	Overall Mean
MEXICO						
Equipment	13.8%	17.8%	41.4%	16.3%	12.3%	8.3%
Buildings and Land	5.9%	7.6%	12.6%	8.1%	7.0%	4.2%
Employment Growth	3.2%	3.9%	5.6%	2.1%	1.0%	0.8%
Sales Growth	9.7%	12.5%	11.5%	6.4%	5.0%	6.4%
COLOMBIA						
Equipment	19.3%	20.2%	47.7%	18.9%	16.8%	14.0%
Buildings and Land	7.9%	9.1%	11.6%	8.3%	7.7%	5.6%
Employment Growth	3.5%	3.8%	4.9%	2.4%	1.5%	0.8%
Sales Growth	6.7%	6.5%	7.3%	4.8%	3.2%	2.4%

t is the year of an equipment investment spike. The means are simple arithmetic means.

Table 4A. Mexico: Sample Conditional Probabilities of Adjustment in Factors of Different Degrees of Flexibility

	Adjustment at time *t* in				
	Labor	Other	Transport	Machinery	Buildings
Given adjustment at time *t* in					
Other	**57.8%**				
Transport	**60.1%**	**51.7%**			
Machinery	**60.7%**	**54.0%**	**52.5%**		
Buildings	**60.7%**	**56.5%**	**52.6%**	**52.3%**	
Land	**52.8%**	47.6%	44.5%	27.9%	31.4%
Memo: Unconditional Probabilities	53.9%	39.4%	39.3%	26.0%	16.6%
	Adjustment at times *t* or *t* -1 in				
	Labor	Other	Transport	Machinery	Buildings
Given adjustment at time *t* in					
Other	**80.6%**				
Transport	**82.7%**	**66.7%**			
Machinery	**83.0%**	**69.4%**	**68.7%**		
Buildings	**82.7%**	**71.0%**	**68.1%**	**64.5%**	
Land	**80.8%**	**66.4%**	**64.6%**	40.6%	41.9%
Memo: Unconditional Probabilities	76.3%	55.9%	56.2%	38.8%	26.2%

Adjustments in fixed capital categories are defined as positive investments exceeding the assumed depreciation rates.

Table 4B. Colombia: Sample Conditional Probabilities of Adjustment in Factors of Different Degrees of Flexibility

	Adjustment at time *t* in				
	Labor	Office	Transport	Machinery	Buildings
Given adjustment at time *t* in					
Other	**57.0%**				
Transport	**56.6%**	**62.9%**			
Machinery	**56.1%**	**62.7%**	44.6%		
Buildings	**54.9%**	**65.2%**	48.3%	**62.9%**	
Land	**54.9%**	**61.3%**	**51.2%**	**54.9%**	47.0%
Memo: Unconditional Probabilities	48.0%	44.6%	33.4%	41.1%	22.7%
	Adjustment at times *t* or *t* -1 in				
	Labor	Office	Transport	Machinery	Buildings
Given adjustment at time *t* in					
Office	**80.4%**				
Transport	**79.1%**	**77.9%**			
Machinery	**79.7%**	**77.3%**	**59.4%**		
Buildings	**79.3%**	**79.7%**	**64.9%**	**79.0%**	
Land	**78.2%**	**76.9%**	**69.9%**	**75.5%**	**59.3%**
Memo: Unconditional Probabilities	72.1%	60.7%	46.7%	58.9%	32.7%

Adjustments in fixed capital categories are defined as positive investments exceeding the assumed depreciation rates.

FOOTNOTES

[1] Dixit and Pindyck (1994), Caballero (1999), and Hitsch (1997) survey the literature on irreversible and lumpy investment. Hamermesh and Pfann (1996) provide a more general survey on factor adjustment costs. Bertola and Caballero (1994) and Caballero and Engel (1998) discuss the aggregate implications of irreversible investment.

[2] The extent to which the standard representative-firm model remains a good description of aggregate investment is an empirical matter. Cooper and Haltiwanger (2000) find that convex adjustment costs models fit aggregate investment time series fairly well, except at turning points.

[3] We do not have data on retirement of capital other than sales, which are small and very infrequent. There is no episode in which sales and purchases of capital exactly offset each other.

[4] One reason why larger plants experience fewer episodes of zero investment is that the within-plant aggregation of manufacturing activities smoothes out investment indivisibilities. In addition, large plants are less likely to experience financial constraints.

[5] See Gelos and Isgut (1999) for further descriptive analysis.

[6] Estimating this model or a logit model with fixed effects would yield biased results given the limited number of time periods. On the other hand, maximizing the conditional likelihood following Chamberlain (1980) is not adequate in the presence of lagged dependent variables.

[7] See also NS (1997). Frank Windmeijer kindly provided a program to implement this estimator.

[8] A spell starts at the year after an investment spike. The estimations for Mexico (Colombia) are based on 2,973 (6,779) spells for high spikes and 7,563 (14,004) for the low spike definition.

[9] The cash-flow variable was positive and statistically significant in the Mexican data set. For evidence of financial constraints in Mexico and Colombia see, respectively, Gelos (1998) and Tybout (1983).

[10] Since we cannot condition on all the variables used in their estimations, while the shape of the hazard is correct, the probabilities shown in the graphs are not exact.

[11] We also estimated hazards using NS's relative spike definition, but our results did not differ significantly from those obtained with the high spike definition.

[12] One might believe nonconvexities to be more important for investment in land and structures than for equipment. However, estimations for this category of capital (not shown) did not yield increasing hazards, either.

[13] In the case of Colombia, for example, the average serial correlation coefficients were .103 for machinery and .066 for buildings and structures.

[14] Under certain conditions, it may also be difficult to distinguish between time-to-build and irreversibilities. If an asset is characterized by a long time-to-build, a firm might be reluctant to invest in it in the face of a large positive shock if it believes that the shock is temporary.

[15] We exclude capital expansions smaller than the depreciation rate because they are likely to represent minor repairs or purchases of parts needed to keep the capital stock in working condition.

[16] Depending on model specifics, the patterns found could put into question the time-to-build hypothesis. For example, if plants were starting from scratch or if there were strong complementarities between machinery and structures, a longer time-to-build for structures would make adjustment in that type of capital good to precede adjustment in machinery.

[17] Following the approach of Caballero, Engel and Haltiwanger (1997), Gelos (1998) shows that adding higher moments of cross-sectional plant characteristics clearly helps to improve the fit of aggregate investment regressions. These results, which we corroborated for Colombia, seem to suggest that the standard convex adjustment cost model does not provide an adequate description of aggregate investment.