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Interrelatedness, Dynamic Factor Adjustment Patterns and Firm Heterogeneity in Austrian Manufacturing

by

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Abstract

The aim of this paper is twofold: one, it analyzes the dynamic factor adjustment patterns and performance changes of firms in response to periods of rapid adjustment of capital, labor, production and non-production labor; and, two, it sheds light on the role of firm characteristics on the probability of any input spike occurring. Firm-group information incorporated in the Austrian Industry Statistics Survey provides the empirical platform for the analysis.

The analysis shows that all input factors considered represent strategic complements and, in the light of skill-technology complements, it proves the absence of any skill bias to the adoption of leading-edge technologies embodied in new machinery and equipment. Furthermore, there is evidence of significant temporary disruptive effects of input spikes on labor productivity and profitability.

Non-negligible firm heterogeneity also prevails in Austrian Manufacturing with larger firm-groups and firm-groups facing lower average personnel costs being more likely to experience any input spike. And the strongly regulated labor market in Austria appears to favor non-production workers.

I. Introduction

Recent and extensive empirical evidence on micro-level data emphasizes the presence of non-negligible jumps in input adjustment patterns, irrespective of input or state of economic development considered or industry chosen. Such rapid input adjustments, however, do not occur in isolation but, by nature, necessitate additional adjustments in strategic complements or substitutes and bring about changes in economic performance.

To identify and describe interrelatedness and dynamic adjustment processes associated with observed input spikes, the analysis focuses on key inputs like employment and skill-related subcomponents like non-production and production labor as well as investments in equipment and machinery and on performance indicators like output, labor productivity or profits.

With respect to labor, Austria is of particular interest since its labor market is strongly regulated with institutions, rules and regulations aimed at helping achieve a higher level of employment under socially acceptable and fair conditions. Particularly, relatively restrictive firing rules regulating individual and collective dismissals encompassing long pre-notification periods, high financial compensations governed by the length of service and lengthy discussions with trade unions and approval of the works council prior to planned layoffs were enacted. In addition, shop stewards, handicapped and women on maternity leave represent specifically protected individuals. Given all said labor market regulations, labor as an input in production becomes less flexible and any planned modifications in employment levels are not immediately translated into actual changes but spread out over more periods, hence employment adjustment is expected to be less jumpy and intermittent.

Additionally, from a vintage-model point of view, investments in equipment and machinery are of interest. Accordingly, newly implemented machinery and equipment embodies recent and productivity enhancing technological developments and knowledge and acts as carrier of technology across industries and countries. The presence of technology-skill complementarities as documented by Bartel and Lichtenberg (1987) as well as the temporary loss of labor productivity during periods of retooling and reorganization that disrupt smooth production processes becomes an interesting issue to analyze.

Furthermore, empirical micro-level evidence shows that only a relatively small fraction of employment restructuring and investment projects is realized in a spike-like manner, revealing non-negligible micro-heterogeneity in adjustment behavior. Identification of firm characteristics associated with observed adjustment spikes becomes a vital research thrust. And since the state of the economy is also expected to impact on rapid input adjustments, macroeconomic indicators are included in the analysis to tackle issues of cyclicality of input spikes or asymmetric hiring and firing activities.

Methodologically, an indicator approach is applied for the first research question that sheds light on factor interrelatedness, i.e. input factor adjustment dynamics in response to lumpy adjustment episodes. Specifically, the response of any particular input to any input spike in the year of, the year after or the year preceding said spike is identified, where dummy variables capture the prevalence of any spike in the current, previous or next period.

The second research question as to the role of firm-heterogeneity in determining the probability of any positive or negative input spike is tackled by using a binary response logit-model, where control variables' quartiles are included to capture dynamic effects.

To account for a potential missing variables bias, both analyses include the same set of explanatory variables, controlling for macroeconomic and firm-level properties. A unique sample of Austrian Manufacturing firm-groups for the period 1982 to 1991 is subject to the analysis.

With on average less frequent and less lumpy labor spikes, the results indicate that prevailing labor market regulations appear to have an effect on employment adjustments. Furthermore, there is considerable interrelatedness observable, all pointing towards strong complementarities between equipment investments, employment, production and non-production labor, supporting the hypothesis of technology-skill complementarities as advocated by Bartel and Lichtenberg (1987). Hence, no evidence of any skill bias in the implementation of leading-edge technologies was detected.

Additionally, results for performance indicators like output, labor productivity or profitability point towards asymmetric adjustment processes in response to either investment or labor-related spikes. In particular, the idea of a temporary disruptive effect of newly implemented machinery and equipment on smooth and routinized production processes only appears in the context of relative equipment investment spikes. Furthermore, while major reductions in non-production labor significantly reduce profitability, drastic personnel cuts of production labor, however, exhibit no significant effect on firm-group profitability.

The spike-occurrence probability analysis reveals strong firm heterogeneity and identifies production labor as the more flexible and consequently less expensive factor in terms of positive or negative adjustments. Firm-group size also matters for spike occurrence with small firms being less likely to experience any positive spike. Non-production labor asymmetrically responds to changing personnel costs which highlight the importance of accumulated firm-specific knowledge over any cost considerations. Finally, neither the gender composition of the workforce nor labor productivity exerts much effect on any spike occurring.

The paper is organized in two sections. While section II gives provides an overview of related empirical evidence, section III describes the data and provides results for the degree of interrelatedness prevailing between different input factors while section IV emphasizes the role of firm heterogeneity for lumpy input adjustment dynamics and discusses firm-group characteristics that are associated with any drastic input modifications. Finally, section V concludes.

II. RELATED RECENT LITERATURE

Numerous studies have emphasized the lumpy nature of firms' input adjustment behavior with periods of more or less zero changes being superseded by periods of feverish non-negligible changes[1]. Irrespective of country, industry or capital good considered, a series of "stylized facts" emerges from this literature for investment as well as employment adjustment patterns:

One, as suggested by Gelos and Isgut (2001) and Fuentes et al. (2005) in their studies on Columbia and Mexico on the one hand and Chile on the other, investment activities appear lumpier in developing countries as compared to developed countries which is predominantly attributed to shallow capital goods markets or underdeveloped capital markets for external funding ; two, in their analyses on capital good specific investment dynamics, Nilsen and Schiantarelli (2003), Attenasio et al. (2003) and Fuentes et al. (2005) stress that investment adjustments are more sporadic for buildings and vehicles as compared to machinery; three, the majority of investment activities occurs in just three years; four, aggregation appears to cushion prevailing lumpiness so that input adjustment patterns are found to be jumpier for plants compared to firms and are smoothed away at the macro-level, and five, Doms and Dunne (1998), Nilsen et al. (2003), Attenasio et al. (2003) as well as Fuentes et al. (2005) emphasize that smaller or younger plants and plants that undergo changes in organizational structure as well as plants that switch industries show lumpier investment patterns.

Additionally, in line with results found by Nielsen et al. (2003) on Norway, in their study on Portuguese establishment data Varejão and Portugal (2007) show that the probability of employment changes is lower for smaller plants which is suggestive of more intermittent employment adjustment patterns. And Nilsen et al. (2005) and Varejão and Portugal (2007) found that employment adjustment patterns are lumpier for separations than for hirings.

However, all above-mentioned studies examine the adjustment of only one input factor of production in isolation and ignore any potential interrelatedness between labor and capital, particularly during periods of rapid input changes. In that respect, Letterie et al. (2004), Sakellaris (2004) and Nilsen et al. (2006) highlight that capital and labor are strategic complements. More specifically, in their study on plants in the Dutch manufacturing sector for 1978 to 1992 Letterie et al. (2004) find that employment and investment decisions are considerably interrelated in that employment changes are significantly higher in the year of as well as in the years preceding and succeeding any investment spike and investment rates are significantly higher (lower) in the year of a positive (negative) employment spike.

[1] For capital adjustments see: Doms and Dunne (1998), Caballero, Engel and Haltiwanger (1995a), Cooper, Haltiwanger and Power (1995), Barnett and Sakellaris (1998) for the US, Carlsson and Laséen (2005) for Sweden, Nilsen and Schiantarelli (2003) for Norway, Attenasio, Pacelli and do Reis (2003) for the UK, Verick, Letterie and Pfann (2004) for West-Germany, Letterie and Pfann (2007) for the Netherlands, Licandro, Maroto and Puch (2005) for Spain, Gelos and Isgut (2001) for Columbia and Mexico and Fuentes, Gilchrist and Rysman (2005) for Chile.
For labor adjustments see: Hamermesh (1989), Caballero, Engel and Haltiwanger (1995b) for the US, Rota (2001) for Italy, Varejão and Portugal (2007) for Portugal and Nilsen, Salvanes and Schiantarelli (2003) for Norway.

The early employment adjustments ahead of any investment spikes are suggestive of preparatory training activities to better absorb major changes in capital stocks and production processes.

Furthermore, Sakellaris (2004) looks at a set of plants operating in the US manufacturing sector between 1972 and 1993, and highlights that capital and labor, in terms of production and non-production labor, represent strategic complements. Moreover, he shows that production labor is the more flexible labor input factor and experiences more rapid adjustments accomplished in a year only while non-production labor adjustments are smoothed out over a couple of years.

And Nilsen et al. (2006) for a set of Norwegian firms in the two Manufacturing industries and one Service industry for 1995 to 2003 find that man hours, as the labor input factor, and capital are strongly contemporaneously interrelated.

Nilsen et al. (2006) and Sakellaris (2004) also study the effect of investment or employment spikes on firm performance indicators like output or sales, labor productivity or total factor productivity and stress that any positive or negative input spikes are accompanied by almost proportional changes in sales or output. In line with results found by Huggett and Ospina (2001), Sakellaris (2004) emphasizes that labor productivity temporarily falls in response to positive investment spikes while only minor and insignificant changes emerge in Nilsen et al. (2006). These results are indicative of temporary disruption costs associated with major technology upgrading. In terms of total factor productivity, results again point toward prevailing temporary disruption costs associated with major positive or negative employment or capital adjustments and highlight the importance of learning-by-doing dynamics associated with improvements in productivity preceding any drastic input adjustments.

III. INPUT SPIKES AND INTERRELATEDNESS

III.1. Data and Descriptive Statistics

Data on firm characteristics and behavior are taken from the Austrian Industry Statistics Survey (Industriestatistik), conducted by Statistics Austria for 37 industries in Industry covering the period 1982-91. The Industry Statistics survey is an annual survey collecting data on individual firm's economic structure and success and has been carried out since 1969. By EU-decree, the Business and Consumer Survey replaced the Industry Statistics Survey in 1996 and was first conducted in 1997.

Given binding legal restrictions on data confidentiality, individual firm observations are unavailable, however. Instead, firm-groups were generated based on similar size-characteristics approximated by total employment. Specifically, all firms within each industry were ranked according to size in 1982 and grouped together to form firm-groups comprising at least 4 firms. A unique identification number was assigned to each firm-group in the database to facilitate tracing its evolution. A balanced set of 839 firm-groups is available.

The initial gross capital stock of equipment and investment was derived applying the Booked Depreciation Method (BDM) suggested by Broersma et al. (2003) instead of the conventional Perpetual Inventory Method (PIM). While PIM derives productive capital by summing past investment flows and correcting for loss of productive capacity due to aging, its major drawback rests in the need for long time series of investments that cover the entire period of the underlying service life. This is particularly problematic in studies on micro-level phenomena where investment series are normally available for a short period only, not fully covering service lives of individual capital assets[2].

The BDM methodology results in zero or negative initial equipment capital stocks for 6 firm-groups. Said observations were eliminated from the analysis.

As a proxy for productivity enhancing investments in new and technologically sophisticated machinery and equipment, the investment rate is defined as the ratio of new investments in machinery and equipment over the total machinery and equipment capital stock $(I/K)_{it}$. The labor related input variables - as potential strategic complements/substitutes for new equipment investments - are measured in terms of growth rates as $(\Delta L/L)_{it}$, $(\Delta NPL/NPL)_{it}$ and $(\Delta PL/PL)_{it}$ for employment, non-production and production labor, respectively. Frequency distributions of the variables are depicted in Figure 1 in the appendix.

III.2. Methodology

This section aims to analyze the interrelatedness of large technology-related production input adjustments as well as associated dynamic adjustment patterns of different variables in response to such large adjustment episodes.

Specifically, light is shed on how firm-groups modify overall employment levels (L), non-production labor (NPL) and production labor (PL) levels in periods of investment spikes (I) in addition to non-production labor levels (respectively, production labor levels) in periods of production labor (respectively, non-production labor) spikes as well as in the preceding and subsequent periods. Furthermore, adjustment dynamics of overall output, labor productivity and total capital stock around and during episodes of large equipment investment, employment, production and non-production labor spikes are analyzed.

[2] For a detailed discussion refer to appendix A.

Depending on the factor analyzed, different definitions of spikes are considered and specified:

- In accordance with the definition suggested by Power (1998), relative investment spikes (REL) are observed if the firm-group investment rate exceeds its median investment rate over the entire time span by 75 %.
- A firm-group undergoes an absolute investment spike (ABSOL) if its investment rate exceeds 20 % for a given year.
- Motivated by Sakellaris (2000), a positive employment spike (POS) is observed if the firm-group growth rate of overall employment is greater than 10 % for a year in absolute terms. A negative employment spike (NEG) is identified if the growth rate of overall employment is lower than 10 % for a given year in absolute terms.
- Likewise, positive and negative production and non-production labor spikes (POS and NEG, respectively) are defined accordingly with an annual growth rate of more than 10 % indicating a positive spike and an annual growth rate of less than 10 % specifying a negative spike, all in absolute terms.

Additionally, in order for an observation to qualify as a spike-event the firm-group has to have all relevant data for the time window around the event. Given the short time horizon available, only the year preceding and succeeding such an event as well as the year of the event are subject to the analysis that follows.
Exceptional outliers with investment ratios exceeding one for one or more periods were excluded from the analysis to avoid contamination of the results. Only 5 observations were subject to this cleansing strategy.

Analogous to Sakellaris (2000) and Letterie et al. (2004), indicator variables are used to pin down the timing of lumpy adjustment periods. Per spike variable V considered, three time-dependent indicator variables are specified as V_k with $V = \{I, L, PL, NPL\}$ and $k = \{previous, current, next\}$.
To identify the relationship between the timing of a spike event V and the variable of interest X_{it} for firm-group i in year t, the following equation is estimated:

$$X_{it} = \mu_i + \sum_{k=-1}^{+1} \theta_k V_{it}^{t+k} + \alpha_t Y_t + \beta_{it} Z_{it} + \varepsilon_{it}$$

where μ_i are firm-group fixed effects to account for unobserved firm-group heterogeneity, the vector Y_t contains macroeconomic controls like real GDP growth and the growth rate of equipment investments, while the vector Z_{it} includes firm-group specific characteristics like size, average personnel costs, the non-production labor share, the gender ratio as well as labor productivity, broken down into respective percentiles to also capture dynamic size-related effects[3]. X_{it} specifies either the investment rate $(I/K)_{it}$, the employment growth rate $(\Delta L/L)_{it}$, the non-production $(\Delta NPL/NPL)_{it}$ or the production labor growth rate $(\Delta PL/PL)_{it}$. The indicator variable V_k is equal to 1 if the firm-group experienced a spike event in either the previous, current or next period. To control for unobserved (time invariant) firm heterogeneity, above equation is estimated using two standard panel data models, fixed effects and random effects models. As the Hausman test rejects the null hypothesis of no correlation between the right hand side variables and the random effects in the model, results for fixed effects estimations will be reported only. The sample summary statistics are reported in Table 11 in appendix C.

Table 1: Absolute frequency of lumpy input adjustments

	POS	NEG	ABSOL	REL
Investment	-	-	437 (239)	1378 (628)
Employment	896 (727)	872 (553)	-	-
Non-Production Labor	1175 (813)	1021 (693)	-	-
Production Labor	1069 (834)	1018 (605)	-	-

Total number of year-group observations: 8260
POS and NEG refer to positive or negative employment, non-production or production labor spikes (as defined above), while ABSOL and REL denote absolute or relative equipment investment spikes (as defined above).

Table 1 reports the frequency of lumpy input adjustments for the 10-year sample according to above outlined definitions where the first number refers to the absolute number of spikes observable in the panel, while the number in parentheses refers to the number of firm-groups that have all relevant data for the three-year time window around the spike event.

Relative equipment investment spikes are three times as frequent as absolute equipment investments spikes. Generally, negative labor-related spikes are less frequent than positive ones, pointing at the potential role of labor market regulations in impeding major personnel cuts. Compared to non-production or production labor, employment shows significantly less frequent positive as well as negative spikes which stress the importance of rich and dynamic adjustment processes at work in skill-related subcategories. Additionally, non-production labor underwent significantly more positive adjustment episodes.

Table 2: Summary statistics of analyzed input spikes

	POS		NEG		ABSOL		REL	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Investment	-	-	-	-	0.3069	0.1214	0.1794	0.1151
Employment	0.2387	0.2694	-0.1946	0.1244	-	-	-	-
Non-Production Labor	0.2683	0.3081	-0.2150	0.1357	-	-	-	-
Production Labor	0.2493	0.3123	-0.2030	0.1346	-	-	-	-

Mean and standard deviation of all positive, negative, absolute or relative input spikes analyzed. POS and NEG refer to positive or negative employment, non-production or production labor spikes (as defined above), while ABSOL and REL denote absolute or relative equipment investment spikes (as defined above).

Table 2 shows summary statistics of all input spikes observed in the 10-year panel and highlights prevailing spike-asymmetries. Specifically, on average, positive labor-related spikes are significantly

[3] For more detailed information on the control variables refer to section III.

higher and more dispersed compared to negative ones. Both, in terms of positive as well as negative spikes, non-production labor exhibits higher average adjustment rates than production labor.

III.3. Results

Results for any effects of absolute or relative equipment investment spikes in previous, current or next periods on changes in employment growth and changes in non-production and production labor growth rates are presented in Panels A, B and C in Table 3 below.

All in all, the results point at a positive relationship between absolute investment spikes and the three employment variables considered and supports the widely held view of capital-labor and equipment-skill complementarities with new technology embodied in new machinery and equipment as suggested by Bartel and Lichtenberg (1987) for the US economy and Flug and Hercowitz (2000) for a sample of 38 developing and developed countries for the mid-1980s to 1991. Contrary to above analyses based on aggregated data, firm-level dynamics points at equipment to strategically complement production and non-production labor – as proxies for unskilled and skilled labor, respectively. In line with Letterie et al. (2005), relative investments spikes are found to generate responses in close resemblance to those of absolute investment spikes.

III.3.1. Effects of Investment Spikes

The results in Panel A suggest that employment growth rates are significant and high during episodes of absolute investment spikes but insignificantly related to spikes occurring in preceding or succeeding periods. This highlights that equipment investments and employment are contemporaneous strategic complements and strongly interrelated.

Panels B and C present results for different skill related types of labor.

Panel B indicates that absolute investment spikes are associated with increases in non-production labor growth rates. More specifically, non-production labor growth significantly increases in the period of an absolute investment spike, possibly for reasons of increased organizational and administrative complexity associated with firm expansion in terms of the capital stock and the production apparatus.

In contrast to effects on non-production labor growth rates, however, Panel C emphasizes that production labor growth rates experience increases prior to, after as well as in the year of investment spikes with stronger contemporaneous effects. Preparatory training activities ahead of investments as well as the realization of insufficient labor operating new machineries and equipment help explain the identified patterns.

Table 3: Effects of previous, current or future absolute or relative investment spikes

A. Effect on employment		
	Absolute	Relative
Previous	0.0108 (0.86)	0.0208 (3.04)***
Current	0.0317 (2.83)***	0.0231 (3.70)***
Next	0.0085 (0.74)	0.0132 (2.04)**
B. Effect on non-production labor		
	Absolute	Relative
Previous	0.0265 (1.64)	0.0323 (3.48)***
Current	0.0344 (2.40)**	0.0214 (2.52)**
Next	0.0236 (1.60)	0.0145 (1.65)*
C. Effect on production labor		
	Absolute	Relative
Previous	0.0306 (2.13)**	0.0223 (2.91)***
Current	0.0394 (3.08)***	0.0171 (2.44)**
Next	0.0315 (2.40)**	0.0209 (2.89)***

The dependent variable is the growth rate of employment (Panel A), non-production labor (Panel B) or production labor (Panel C) while the independent variables are dummy variables to indicate whether an absolute or relative investment spike (as defined above) has occurred in the previous, current or next period as well as quartiles of size, personnel costs, non-production labor shares, gender-ratios and labor productivity and the growth rate of Austrian real GDP and the equipment investment deflator to capture macroeconomic dynamics. To account for firm heterogeneity, i.e. unobservable and time-invariant firm characteristics, fixed as well as random effects logit models were calculated. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specification only.
Absolute values of t-statistics are in parentheses.
*Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level.

Similar to inferences drawn by Letterie et al. (2004) for the Dutch manufacturing sector, the definition of investment spikes also hardly matters for adjustment patterns in Austrian manufacturing with comparable responses of employment, non-production and production labor growth rates to either absolute or relative investment spikes.

III.3.2. Effects of Employment Spikes

The relationship between previous, current and future positive or negative employment spikes and equipment investment rates is reported in Table 4 below.

Table 4: Effects of previous, current or future positive or negative employment spikes

A. Effect on equipment investment		
	Positive	Negative
Previous	0.0107 (3.44)***	-0.0058 (1.61)
Current	0.0177 (5.67)***	-0.0035 (0.94)
Next	0.0053 (1.62)	0.0040 (0.99)

The dependent variable is the equipment investment rate while the independent variables are dummy variables to indicate whether a positive or negative investment spike (as defined above) has occurred in the previous, current or next period as well as quartiles of size, personnel costs, non-production labor shares, gender-ratios and labor productivity and the growth rate of Austrian real GDP and the equipment investment deflator to capture macroeconomic dynamics. To account for firm heterogeneity, i.e. unobservable and time-invariant firm characteristics, fixed as well as random effects logit models were calculated. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specification only.
Absolute values of t-statistics are in parentheses.
*Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level.

Equipment investment rates are significantly associated with positive employment spikes and turn out to be higher during as well as after episodes of rapid positive employment adjustments with stronger contemporaneous effects. Preparatory training measures help to explain the emerging picture where considerable employment growth precedes expansions of the stock of machinery and equipment. Additionally, the results indicate that equipment investment rates are insignificantly related to the occurrence of negative employment spikes. Overall, there is ample evidence that employment and equipment investments are considerably but asymmetrically interrelated.

III.3.3. Effects of Non-Production Labor Spikes

Panels A and B of Table 5 help shed light on the relationship between previous, current or next non-production labor spikes and equipment investment rates or production labor growth rates. Both, equipment investments and production labor are contemporaneous complements to positive non-production labor spikes. Moreover, production labor growth rates are also significantly higher in periods following a positive non-production labor spike.

Table 5: Effects of previous, current or future positive or negative non-production labor spikes

A. Effect on equipment investment		
	Positive	Negative
Previous	0.0049 (1.63)	0.0002 (0.07)
Current	0.0088 (2.95)***	-0.0024 (0.70)
Next	0.0036 (1.16)	0.0015 (0.42)
B. Effect on production labor		
	Positive	Negative
Previous	0.0150 (2.06)**	-0.0017 (0.20)
Current	0.0549 (7.55)***	-0.0587 (6.45)***
Next	0.0017 (0.23)	0.0099 (1.03)

The dependent variable is the equipment investment rate (Panel A) or the production labor growth rate (Panel B) while the independent variables are dummy variables to indicate whether a positive or negative non-production labor spike (as defined above) has occurred in the previous, current or next period as well as quartiles of size, personnel costs, non-production labor shares, gender-ratios and labor productivity and the growth rate of Austrian real GDP and the equipment investment deflator to capture macroeconomic dynamics. To account for firm heterogeneity, i.e. unobservable and time-invariant firm characteristics, fixed as well as random effects logit models were calculated. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specification only.
Absolute values of t-statistics are in parentheses.
*Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level.

The results also suggest that only production labor exhibits significant adjustment dynamics associated with negative non-production labor spikes. Specifically, there are significantly lower production labor growth rates in periods of drastic reductions in non-production labor. The analysis further reveals that while production labor is significantly related to both types of non-production labor spikes, equipment investment is only asymmetrically associated with non-production labor spikes and shows no significant relationship with negative spikes.

III.3.4. Effects of Production Labor Spikes

The relationship between previous, current and next period's positive or negative production labor spikes and equipment investment as well as non-production labor growth is presented in Panels A and B of Table 6. The results in Panel A indicate that equipment investment rates are significantly higher in the year of as well as in the year following a positive production labor spike but are unrelated to negative production labor spikes. Training activities in preparation for efficient operation of new and more sophisticated machinery and equipment help to explain the lagged response of equipment investment rates to spikes in production labor.

Table 6: Effects of previous, current or future positive or negative production labor spikes

A. Effect on equipment investment		
	Positive	Negative
Previous	0.0098 (3.36)***	-0.0029 (0.82)
Current	0.0177 (6.01)***	-0.0047 (1.28)
Next	0.0049 (1.57)	0.0031 (0.80)
B. Effect on non-production labor		
	Positive	Negative
Previous	0.0066 (0.83)	0.0028 (0.30)
Current	0.0811 (10.21)***	-0.0585 (5.97)***
Next	0.0055 (0.65)	0.0057 (0.56)

The dependent variable is the equipment investment rate (Panel A) or the non-production labor growth rate (Panel B) while the independent variables are dummy variables to indicate whether a positive or negative production labor spike (as defined above) has occurred in the previous, current or next period as well as quartiles of size, personnel costs, non-production labor shares, gender-ratios and labor productivity and the growth rate of Austrian real GDP and the equipment investment deflator to capture macroeconomic dynamics. To account for firm heterogeneity, i.e. unobservable and time-invariant firm characteristics, fixed as well as random effects logit models were calculated. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specification only.
Absolute values of t-statistics are in parentheses.
*Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level.

As pointed out above, Panel B confirms that production and non-production labor are contemporaneous complements with significantly higher (lower) non-production labor growth rates in the year of a positive (negative) production labor spike.

III.4. Performance Spike Effects

Light is also shed on the dynamic adjustment pattern of levels of output, labor productivity and profits in response to abrupt input adjustments. Output is defined as the value of production, labor productivity refers to the value of production per employee while profits are specified as value added minus taxes, interest payments on debt capital and overall wage costs.
As shown in Panel A of Table 7, the idea of the temporary disruptive effect of newly implemented machinery and equipment on smooth and routinized production processes is only reflected in the context of relative equipment investment spikes where labor productivity is significantly higher in the period preceding said spike only. Additionally, profit responses closely resemble labor productivity responses with immediate effects for absolute but lagged effects for relative investment spikes.

Table 7: Results for Output, Labor Productivity and Profits

A. EFFEKT OF ABSOLUTE OR RELATIVE EQUIPMENT INVESTMENT SPIKES ON												
	Output				Labor Productivity				Profits			
	ABSOLUTE		REALTIVE		ABSOLUTE		RELATIVE		ABSOLUTE		RELATIVE	
Previous	0.057	(4.12)***	0.043	(5.09)***	0.019	(1.83)*	0.014	(2.21)**	0.001	(0.02)	0.043	(1.75)*
Current	0.070	(5.71)***	0.035	(4.48)***	0.020	(2.07)**	0.005	(0.77)	0.103	(2.79)***	0.035	(1.53)
Next	0.016	(1.24)	0.017	(2.12)**	-0.005	(0.47)	-0.001	(0.16)	0.038	(1.00)	0.038	(1.63)

B. EFFEKT OF POSITIVE OR NEGATIVE EMPLOYMENT SPIKES ON												
	Output				Labor Productivity				Profits			
	POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE	
Previous	0.058	(8.22)***	-0.038	(4.69)***	-0.009	(1.58)	0.013	(1.91)*	0.101	(4.44)***	-0.081	(3.26)***
Current	0.075	(10.61)***	-0.064	(7.62)***	-0.028	(4.61)***	0.023	(3.32)***	0.088	(3.82)***	-0.077	(2.95)***
Next	-0.048	(6.45)***	0.066	(7.37)***	0.026	(4.16)***	-0.026	(3.45)***	-0.018	(0.76)	0.069	(2.51)**

C. EFFEKT OF POSITIVE OR NEGATIVE NON-PRODUCTION LABOR SPIKES ON												
	Output				Labor Productivity				Profits			
	POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE	
Previous	0.038	(5.76)***	-0.040	(5.46)***	-0.002	(0.27)	0.007	(1.20)	0.086	(3.99)***	-0.059	(2.61)***
Current	0.037	(5.52)***	-0.052	(6.65)***	-0.026	(4.55)***	0.014	(2.21)**	0.055	(2.57)**	-0.080	(3.40)***
Next	-0.037	(5.27)***	0.041	(5.03)***	0.016	(2.64)***	-0.013	(1.94)*	-0.022	(0.99)	0.086	(3.46)***

D. EFFEKT OF POSITIVE OR NEGATIVE PRODUCTION LABOR SPIKES ON												
	Output				Labor Productivity				Profits			
	POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE	
Previous	0.053	(7.83)***	-0.024	(3.08)***	0.004	(0.76)	0.005	(0.86)	0.063	(2.98)***	-0.016	(0.67)
Current	0.069	(10.22)***	-0.041	(4.92)***	-0.003	(0.47)	0.021	(3.11)***	0.104	(4.90)***	-0.022	(0.84)
Next	-0.044	(6.25)***	0.050	(5.70)***	0.014	(2.49)**	-0.015	(2.11)**	-0.029	(1.31)	0.084	(3.13)***

The dependent variables are either overall output, labor productivity or profits while the independent variables are dummy variables to indicate whether an absolute or relative equipment investment spike or a positive or negative employment, non-production or production labor spike (as defined above) has occurred in the previous, current or next period as well as quartiles of size, average labor costs, non-production labor shares and gender ratios, firm-group dummies and the growth rate of Austrian real GDP and the growth rate of the equipment investment deflator to account for firm heterogeneity and aggregate trends in variables. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specifications only.
Absolute values of t-statistics are in parentheses.
*Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level.

Panels B to D in Table 7 also confirm that irrespective of the labor-related spike indicator considered, output is significantly higher (lower) in the period of and the period following a positive (negative) spike with stronger contemporaneous effects. Furthermore, when comparing the two skill-related labor spikes asymmetric responses of output become apparent: increases in output are stronger in response to positive production labor spikes while drops in output are more significant in response to negative non-production labor.

More complex dynamics are apparent for labor productivity responses: once contrasted with the effects for output, any significant changes in labor productivity turn out to be driven by either drastic positive or negative labor-related spikes. Falling or increasing labor productivities in response to positive or negative labor-related spikes, respectively, are temporary phenomena only and restricted to the period of the spike. Temporary disruptive effects of drastic labor-related adjustment spikes become apparent. Unfortunately, given the analysis' limited time scope, long-term labor productivity effects remain hidden. Interestingly, with respect to production labor, asymmetries emerge which suggest that temporary reductions in labor productivity in response to positive production labor spikes are absent.

Finally, profit dynamics of labor-related input adjustments are considered in Panels B to D in Table 7 which confirms that, except for drastic reductions of production labor, profits are significantly higher (lower) in the year of and following any labor-related positive (negative) spikes. The results therefore suggest that major personnel cuts of production labor are not associated with significant profit reductions.

IV. FIRM CHARACTERISITCS AND SPIKE OCCURRENCE

IV.1. Methodology

This section aims to identify macroeconomic and firm specific characteristics that significantly affect the occurrence of absolute and relative equipment investment as well as positive and negative employment, non-production and production labor spikes for the 10-year firm group sample covered by the Industry Statistics Survey for the period 1982 to 1991.

A logit model – as a binary response model – is applied to specify the effects of different variables on the probability of the occurrence of a spike, where the presence of a spike is modeled as $y = 1$ and the absence of a spike is specified as $y = 0$. In particular, the following specification is analyzed:

$$g(x) = \ln[\frac{\pi(x)}{1-\pi(x)}] = \beta_0 + \beta_1 x_1 + ... + \beta_k x_k \text{ ,}$$

where $\pi(x)$ is the logistic function $\pi(x) = \frac{e^{\beta_1 + x_2\beta_2 + ... + x_K\beta_K}}{1 + e^{\beta_1 + x_2\beta_2 + ... + x_K\beta_K}}$.

The specification is estimated via an iterative Maximum-Likelihood procedure. To control for unobserved firm heterogeneity, above equation is estimated using fixed effects and random effects models. Since the Hausman test rejects the null hypothesis of no correlation between the right hand side variables and the random effects in the model, results for fixed effects estimations will be reported only.

The vector of explanatory variables is restricted by data availability and comprises macroeconomic and firm-specific characteristics. The sample summary statistics are reported in Table 11 in appendix C.

Macroeconomic characteristics

The **annual growth rate** of Austrian real GDP is used to measure the cyclical effect of business conditions on the probability of an input adjustment spike and is expected to negatively affect the spike-probability since – according to the "pit-stop idea of recessions" (e.g. Caballero et al. (1994)) – productivity enhancing activities are undertaken in recessionary times of low opportunity costs. Any change in the level of inputs temporarily disrupts the smooth and routinized production process since workers' assignments need to be rearranged and tasks need to be reassigned and restructured. Hence, productivity and output decline during retooling and reorganization activities. Since the opportunity costs associated with those rearrangements are relatively low in economic downturns, retooling and reorganization should be countercyclical and hence concentrated in economic recessions. On the contrary, Klenow (1997) advocates the role of learning effects for the cyclical behavior of investment activities and technology upgrading and emphasizes that due to higher production rates during economic booms, high learning rates emerge quickly giving rise to higher productivity levels. Additionally, with complementarities between capital and labor on the one hand, and capital and skills on the other, changes in the capital stock and changes in the employment level or the skill-composition of the workforce should take place simultaneously within firms. Empirical results are still inconclusive, however. Cooper and Haltiwanger (1993) highlight countercyclical replacement in the context of a machine replacement problem since overall costs of replacement (i.e. lower labor productivity) are lowest during recessionary periods. Dunne et al. (1996) reveal countercyclical spikes in non-production labor shares. On the contrary, Doms and Dunne (1998) and Cooper et al. (1995) for the US economy and Süssmuth (2003) for Germany both stress the procyclical pattern of large investment episodes for the post and pre World War II periods, respectively.

The growth rate of the **equipment investment deflator** is used to explicitly account for price changes in new equipment and machinery. Technological progress embodied in new machinery and equipment enhances productivity and profitability of investing firms. Rising prices render new machinery and equipment more expensive, depressing adoption activities of new embodied technology. Therefore, a negative relationship between an increasing equipment deflator and the spike-probability is expected. Goolsbee (1998) in his study on the US airline industry from 1972-84 finds that the costs of capital equipment negatively affect the realization of investment projects since costly investments are postponed to more favorable periods.

Firm characteristics

Additionally, average firm-group specific characteristics are included to capture firm-group heterogeneity. Specifically, each dependent variable considered is grouped into quartiles to also account for dynamic size-specific effects.

Average **firm-group size** - as proxied by total employment over firm-group size - is included to capture the size-effect of input adjustments. Since size stems from expansion of employment by profitable firms, larger firm-groups are expected to be more established and have levels of output closer to the minimum efficient scale. Hence, a negative relationship between the probability of a spike and firm-group size is expected. Doms and Dunne (1998) in their study on the US economy find a strong positive but decreasing relationship between plant size and episodes of investment spikes while Varajão and Portugal (2007) discover a strong and negative relationship between plant size and the probability of an employment spike for the Portuguese economy, defined as employment adjustment rates in excess of 10 % in a year.

Average wages paid are defined as the ratio of overall personnel costs (comprising gross wages, and salaries as well as compulsory employers' contributions to the social security system and other social costs) to total employment and represent the average personnel costs per employee. The higher average labor costs the more expensive are employees and therefore the lower expected employment spike-occurrence. On the other hand, higher average labor costs indicate higher investment in training and firm-specific human capital and a positive relationship between the probability of employment spikes and average labor costs is expected.

Endowment of firm specific human capital is also expected to affect the probability of an input spike. Based on observed complementarities between skills and technology (e.g. Bartel and Lichtenberg, (1987) or Golding and Katz, (1998)), technology embodied in newly implemented machinery and equipment are typically operated by skilled laborers. So, a high level of the non-production labor share – proxied by the average ratio of non-production to production labor of the firm-group - is associated with high levels and adoption rates of sophisticated machinery and equipment. And since technologically advanced machinery and equipment is also more productive, a positive relationship between the level as well as the growth rate of the non-production labor share and the probability of a spike is expected. However, Varejão and Portugal (2007) in their study on employment spikes in the Portuguese labor force find a decreasing probability of either a positive or negative employment spike with higher skill shares, measured as the proportion of workers in managerial and technical occupations in total firm employment. This result is attributed to the potentially more demanding and expensive hiring procedures for skilled workers.

The **average gender ratio** – defined as the ratio of female over male employees per firm in the firm-group – is included in the analysis to take account of potential gender related effects on the occurrence probability of an input spike. Varejão and Portugal (2007) determine an asymmetric relationship between the gender ratio (defined as the ratio of male employees over total employment) and the probability of an employment spike in the Portuguese labor force. While there is a significant positive relationship between the gender ratio and a negative employment spike so that expansions of male employment result in higher probabilities of drastic employment reductions, no significant relationship exists between the gender ratio and a positive employment spike.

Finally, **labor productivity** as the ratio of the production value and the overall firm-group employment is included as a control variable to represent the average level of technological sophistication of individual firms. Since superior production technologies result in higher output, sales and potentially profits, the need for the implementation of new production technologies or restructuring of firm labor force is low so that a negative relationship between the level of productivity and the probability of any input spike is expected.

IV.2. Results

Results for the occurrence-probabilities of absolute or relative equipment investment spikes (ABSOL or REL), positive or negative employment growth spikes (L-POS or L-NEG), positive or negative non-production labor growth spikes (NPL-POS or NPL-NEG) or positive or negative production labor growth spikes (PL-POS or PL-NEG) are presented in

Table 8 where independent variables are classified into respective quartiles to also capture the role of between-quartile or size effects on the probability of any spike occurring and expressed relative to the largest quartile as the category of reference. Additionally, focus on both, negative and positive spike behavior should help identify asymmetric dynamics associated with different explanatory variables. For reasons of comparability to results of the previous section, estimated results are reported for any three-year window only where all relevant firm-group specific data around any spike event are available. An overview of expected and actual results found is given in Table 9 and general results are presented Table 12 in appendix C.

The results on the cyclicality of investment spikes turn out to be supportive of Klenow's (1997) idea of learning effects driving adoption of superior production technologies. Additionally, positive labor-related spikes predominantly occur in economic upturns while negative ones are bunched into economic downturns and recessions with more pronounced effects found for production labor as the more flexible and less costly factor to adjust. This latter observation is in line with results found for the UK and the Netherlands (Pfann and Palm (1993)), Spain (Alonso-Borrego (1998)) and Mexico (Robertson and Dutkowsky (2002)) where non-production labor is more costly and hence less prone to experience downward adjustments. Furthermore, no evidence of labor hoarding is found.

Table 8: Regression Results – fixed effects logit for 3-year window

Independent Variables	ABSOL	REL	L-POS	L-NEG	NPL-POS	NPL-NEG	PL-POS	PL-NEG
Real GDP	0.2525	0.1307	0.2334	-0.248	0.1419	-0.135	0.1819	-0.2121
	(3.61)***	(3.12)***	(6.04)***	(6.22)***	(3.93)***	(3.67)***	(4.98)***	(5.41)***
Deflator Equipment	-0.1979	-0.2078	-0.1121	0.0752	-0.1092	0.0118	-0.1058	0.0905
	(4.65)***	(7.52)***	(3.86)***	(2.09)**	(3.96)***	(0.38)	(3.83)***	(2.58)***
1st Size Quartile	-2.5864	-1.3438	-3.2961	3.2105	-1.9979	3.3656	-2.5542	2.2852
	(2.27)**	(2.18)**	(5.02)***	(4.11)***	(3.38)***	(4.25)***	(4.12)***	(3.05)***
2nd Size Quartile	-2.5219	-1.3083	-2.4303	2.2407	-1.4036	2.2387	-2.0702	1.408
	(2.48)**	(2.58)***	(4.16)***	(3.20)***	(2.75)***	(3.08)***	(3.77)***	(2.10)**
3rd Size Quartile	-2.0293	-0.5911	-0.7006	0.6742	-0.6145	1.5207	-0.9278	0.122
	(2.62)***	(1.56)	(1.71)*	(1.21)	(1.61)	(2.40)**	(2.22)**	(0.22)
4th Size Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st PC Quartile	0.0725	0.0685	2.0781	-0.8698	1.4807	-0.1098	1.7924	-0.6588
	(0.21)	(0.32)	(9.78)***	(3.87)***	(7.38)***	(0.54)	(8.85)***	(2.99)***
2nd PC Quartile	0.2067	0.2613	1.3251	-0.6012	1.2119	-0.1186	1.1724	-0.4122
	(0.76)	(1.54)	(7.33)***	(3.26)***	(7.29)***	(0.69)	(6.95)***	(2.33)**
3rd PC Quartile	0.2382	0.2154	0.7873	-0.4626	0.8558	-0.1879	0.6714	-0.3696
	(1.03)	(1.51)	(4.88)***	(2.91)***	(5.85)***	(1.23)	(4.53)***	(2.43)**
4th PC Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st Skill-Ratio Quartile	0.1378	0.3119	0.5798	-0.6855	-2.1911	1.9923	2.0891	-1.7147
	(0.37)	(1.25)	(2.33)**	(2.54)**	(8.99)***	(8.04)***	(8.19)***	(6.44)***
2nd Skill-Ratio Quartile	-0.348	-0.0122	0.3485	-0.3936	-1.3133	1.3226	1.458	-1.1346
	(1.04)	(0.06)	(1.58)	(1.70)*	(6.44)***	(6.09)***	(6.53)***	(5.07)***
3rd Skill-Ratio Quartile	-0.6101	0.0061	0.2463	-0.0988	-0.5159	0.4821	0.8848	-0.4357
	(1.92)*	(0.03)	(1.28)	(0.53)	(3.05)***	(2.56)**	(4.72)***	(2.51)**
4th Skill-Ratio Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st Gender-Ratio Quartile	-0.5919	-0.0816	-0.0297	-0.3255	-0.0985	-0.204	0.0612	-0.3408
	(1.47)	(0.32)	(0.11)	(1.21)	(0.39)	(0.83)	(0.23)	(1.23)
2nd Gender-Ratio Quartile	-0.0496	-0.211	0.3217	-0.3793	0.1768	-0.3407	0.1179	-0.4022
	(0.15)	(0.93)	(1.45)	(1.64)	(0.83)	(1.58)	(0.52)	(1.72)*
3rd Gender-Ratio Quartile	-0.2432	-0.1397	0.1077	-0.0997	-0.0704	-0.0408	0.0827	-0.0758
	(0.87)	(0.74)	(0.56)	(0.54)	(0.39)	(0.22)	(0.44)	(0.42)
4th Gender-Ratio Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st Labor Productivity Quartile	0.0669	-0.2928	0.9248	-0.0899	0.4748	-0.0421	0.606	-0.4023
	(0.18)	(1.22)	(4.10)***	(0.38)	(2.15)**	(0.19)	(2.75)***	(1.68)*
2nd Labor Productivity Quartile	0.2161	-0.0665	0.5367	-0.1684	0.2363	0.0206	0.3825	-0.086
	(0.70)	(0.34)	(2.82)***	(0.83)	(1.27)	(0.11)	(2.07)**	(0.43)
3rd Labor Productivity Quartile	0.2484	-0.1482	0.3601	-0.3197	0.2949	-0.0993	0.3659	-0.2564
	(0.95)	(0.91)	(2.26)**	(1.83)*	(1.89)*	(0.63)	(2.38)**	(1.45)
4th Labor Productivity Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Observations	1780	3520	3789	3098	3976	3569	4059	3193
Number of Groups	178	352	422	346	443	398	452	357
Log likelihood	-456.97	-1119.41	-1143.06	-945.81	-1288.31	-1134.34	-1294.79	-1005.59

The dependent variable is one or zero, depending on whether between 1982 and 1991 a relative or absolute investments spike (ABSOL or REL), a positive or negative employment growth spike (L-POS or L-NEG), a positive or negative non-production labor growth spike (NPL-POS or NPL-NEG) or a positive or negative production labor spike (PL-POS or PL-NEG) has occurred. The independent variables included represent quartiles of size, personnel costs, non-production labor shares, gender-ratios and labor productivity. To account for firm heterogeneity, i.e. unobservable and time-invariant firm characteristics, fixed as well as random effects logit models were calculated. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specification only.
To render results comparable to those of the previous section, estimation results are calculated for a three-year window around any spike-event.
Absolute values of z-statistics are in parentheses.
*Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level.

In line with above inferences on prevailing investment-labor and investment-skill complementarities, price increases of equipment and machinery not only reduce the probability of any investment spike but also significantly lessen the probability of any positive labor-related spikes.

Comparable to conclusions drawn by Varajão and Portugal (2007), the results also emphasize the importance of size-related effects and indicate that positive investment or labor-related spikes are unlikely to occur in small firm-groups while negative spikes are more likely to be observable in small firm-groups.

Additionally, increasing personnel costs renders labor more expensive and decreases the probability of positive labor-related spikes, while the reverse is found for negative labor-related spikes. The results also highlight the absence of any significant cost-related effects on negative non-production labor spikes and point at the importance of firm-specific knowledge. In particular, the cost-disadvantages of increasing personnel costs cannot overcompensate any advantages of accumulated firm-specific knowledge. And surprisingly, despite prevailing investment-labor or investment-skill complementarities found above, rising personnel costs appear to have no significant effect on the probability of any equipment investment spikes occurring.

Further reinforcing dynamics are found for non-production labor shares as defined by the ratio of non-production to production labor: low shares, as characterized by comparably abundant production labor, are associated with positive but decreasing probabilities of positive and negative production labor spikes but increasing probabilities of negative production labor spikes.

All in all, the gender ratio hardly exhibits any significant effect on the occurrence of any input spike.

While labor productivity appears unrelated to any equipment investment spike, initially positive but decreasing effects become obvious for positive employment and production labor spikes.

Table 9: Expected and actual effects of explanatory variables

VARIABLE	Expected Effect on spike occurrence	Actual Effect found
Real GDP growth rate	Positive or negative	Positive
Equipment investment deflator growth rate	Negative	Negative
Average firm-group size	Negative	Negative
Average personnel costs	Positive or negative	Negative
Non-production labor share	Positive	Negative (if any)
Gender ratio	Unclear	None
Labor productivity	Negative	None

V. Summary and Conclusion

Lumpy adjustment of input factors is an empirical fact also for the small and open economy of Austria. The paper attempts to shed light on interrelatedness and dynamic responses of performance indicators associated with rapid adjustments and to identify firm characteristics related with the occurrence of absolute or relative equipment investment spikes and positive or negative labor-related spikes for a sample of manufacturing firms between 1982 and 1991.

The results clearly reveal strong degrees of intertemporal interrelatedness between factors considered.

More specifically, in the light of the implementation of new and technologically more sophisticated machinery and equipment, the role of preparatory training activities for production labor and the potentially increased organizational and administrative complexity for non-production labor becomes apparent. And given the frequency of employment, non-production and production spikes observed, rather stringent labor market regulations seem to affect the employment spike occurrence.

In terms of performance, output, labor productivity and profitability asymmetrically respond to observed spikes. With the exception of production labor, there is evidence of significant temporary productivity and profitability disruptions to drastic input adjustments. Furthermore, the idea of the temporary disruptive effect of newly implemented machinery and equipment on labor productivity depends on the exact definition of the investment spike considered and only finds support in the context of relative equipment investment spikes.

Significant firm heterogeneity is also attested to Austrian Manufacturing.

The size-related effect suggests that larger firms are more likely to grow while smaller ones are more likely to shrink. Personnel costs also matter in that firm-groups facing higher average costs reveal a lower probability of positive labor-related input spikes, an effect that is stronger for production labor, identifying production labor as the more flexible input factor. So if labor regulation exhibits protective effects, they obviously asymmetrically work in favor of non-production labor. Furthermore, a significant role of firm-specific know-how becomes apparent for non-production labor. The gender composition of the labor force hardly matters for input spike occurrence while, unexpectedly, labor productivity appears to hardly have any significant effect.

Finally, in terms of cyclicality of lumpy input adjustment activities, positive spikes are bunched in periods of economic recovery and growth while negative ones are concentrated in economic recessions. The results also highlight the higher degree of flexibility of production labor. Furthermore, consistently procyclical absolute and relative equipment investment spikes are supportive of the learning-effect hypothesis.

The model-free empirical approach applied here helps to identify general patterns of adjustment dynamics and input interrelatedness. For further analysis, the results clearly stress that interrelatedness of input factors as well as firm heterogeneity explicitly needs to be taken into account. Furthermore, determining the structure of adjustment costs in terms of convexities and non-convexities in giving rise to and shaping spike-like input adjustment behavior is the natural path to follow next. This research thrust will also help verify the differential adjustment cost structure found for non-production and production labor.

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VII. Appendix A

The Booked Depreciation Method starts from the idea that provided firms' accounting practices are known to be subject to linear depreciation with equal deprecation per year over the service life of an asset and annual depreciation is available, booked depreciation contains information on investments undertaken in the past. Specifically, with a lifetime of L of an asset, booked depreciation is

$$D_t = \sum_{p=1}^{L} \frac{1}{L} I_{t-p} \tag{1}$$

and with the simple extension that $D_{t+1} - D_t = \frac{1}{L} I_t - \frac{1}{L} I_{t-L}$, investment in period $t - L$ and therefore past investment series can be derived by means of future investment and reported booked depreciations as

$$I_{t-L} = I_t + L(D_t - D_{t+1})\ . \tag{2}$$

The required service lifetimes (L) of equipment and machinery in diverse industries are taken from OECD (1993), estimated on information supplied by enterprises, on estimates reported by other countries and on expert advice.

Investment and booked depreciation series are available for the period 1982–1991. Exemplified by the case of an industry with a service lifetime of 22 years reported for equipment and machinery, two subperiods are created covering 1960-1968 and 1969-1981. Hence, the nominal capital stock of the respective industry in 1982 - the initial year of the firm-group panel – is calculated as follows:

$$nK_{82} = \sum_{t=60}^{81} \frac{(t-60+1)}{22} I_t = \sum_{t=60}^{68} \frac{(t-60+1)}{22} I_t + \sum_{t=69}^{81} \frac{(t-60+1)}{22} I_t \tag{3}$$

It can be shown that the first term on the right hand side of above equation can be approximated by applying above intuition on the derivation of past investment series on the basis of available investment and depreciation series as

$$I_t = 22(D_{t+22} - D_{t+23}) + I_{t+22} \qquad \text{with } t = (60,...,68) \tag{4}$$

The second term can be approximated by

$$\sum_{t=69}^{81} \frac{(t-60+1)}{22} I_t \approx \left(\frac{16}{22}\right) \sum_{t=69}^{81} I_t \qquad \text{with } t = (69,...,81) \tag{5}$$

With reference to (1), the sum of depreciation over the period equals

$$\sum_{t=82}^{91} D_t = \left(\frac{1}{22}\right)\left(\sum_{t=69}^{90} I_t + \sum_{t=70}^{89} I_t + \sum_{t=71}^{88} I_t + \ldots + \sum_{t=60}^{81} I_t\right) \tag{6}$$

and can be rewritten as the sum of the following three terms:

$$\sum_{t=82}^{91} D_t = \left(\frac{10}{22}\right)\sum_{t=69}^{81} I_t + \sum_{t=82}^{90} \frac{(90+1-t)}{22} I_t + \sum_{t=60}^{68} \frac{(t-60+1)}{22} I_t \tag{7}$$

And rewriting and rearranging gives the following expression that allows derivation of the equipment investment series needed to approximate (5), where the first and second term can be observed from the data while the third one needs to be derived from (4):

$$\sum_{t=69}^{81} I_t = \left(\frac{22}{10}\right)\sum_{t=82}^{91} D_t - \sum_{t=82}^{90} \frac{(90+1-t)}{10} I_t - \sum_{t=60}^{68} \frac{(t-60+1)}{10} I_t \ . \tag{8}$$

Finally, the real capital stock in 1981 in constant 1984 prices is derived by deflating the investment flows between 1982 and 1990 with the annual aggregate price index for gross fixed capital formation in equipment and machinery available for 1964 and 2005. Additionally, investment flows for the period 1960-1968 are deflated by the average annual price index for gross fixed capital formation for said period.

$$K_{82} = \sum_{t=60}^{68} \frac{(t-60+1)}{22} I_t \left(\frac{P_{i,84}}{P_{i,t}}\right) + \sum_{t=69}^{81} \frac{(t-60+1)}{22} I_t \left(\frac{P_{i,84}}{avP_{69,81}}\right) \tag{9}$$

The overall series of real capital stocks of equipment and machinery is derived by adding investments to depreciated last period's capital stock:

$$K_t = K_{t-1}[1-\delta] + I_t$$

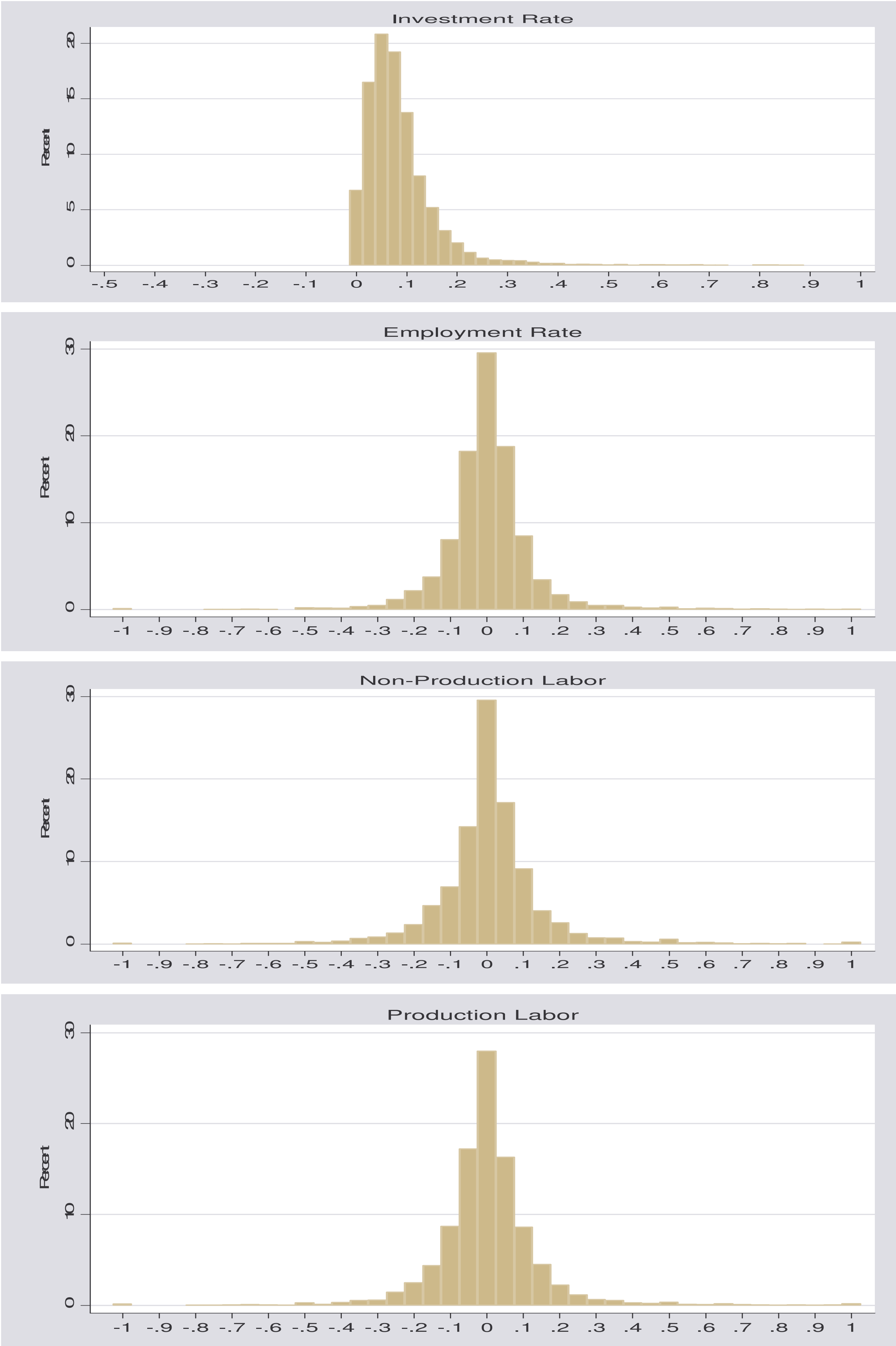
where a linear and industry-specific depreciation of equipment and machinery specified as $\delta = 1/L$ is applied (see appendix for industry-specific service lifetimes and depreciation rates).

VIII. Appendix B

Table 10: Industry service lives of machinery and equipment (excluding vehicles)

Industry code	Name	# of firm-groups	Match	Service lives for machinery and equipment	Depreciation Rate (1/Lifetime)
12	Gas supply	7	Gas	18	0.06
13	Thermal energy supply	8	Energy	18	0.06
14	Water supply	44	Water	18	0.06
21	Mining of coal	1	Coal Mining	20	0.05
22	Mining of metal ores	1	Iron-ore mining	20	0.05
23	Mining of crude oil and gas	1	Petroleum and Gas	20	0.05
24	Mining of salt	1	Mining and Quarrying	20	0.05
25	Mining of magnetite	1	Mining and Quarrying	20	0.05
26	Mining of graphite, talc, gypsum and other minerals	3	Mining and Quarrying	20	0.05
27	Quarrying of stones and soil	16	Mining and Quarrying	20	0.05
31	Food	62	Food and beverages	22	0.05
32	Beverages and tobacco	28	Tobacco	22	0.05
33	Textiles	64	Textiles	17	0.06
34	Wearing apparel	56	Textiles	17	0.06
35	Footwear	8	Clothing	17	0.06
36	Leather	5	Leather	17	0.06
37	Processing of wood and products of wood	9	Lumber and wood products	15	0.07
38	Furniture	48	Furniture	15	0.07
39	Musical instruments, sports equipment and toys	5	Other Manufacturing	**18**	0.06
41	Paper and paper products	28	Paper and paper products	18	0.06
42	Printing and publishing	1	Printing and Publishing	15	0.07
44	Rubber and plastic products	24	Rubber, Plastic Products	18	0.06
45	Chemicals and allied products	54	Chemicals	18	0.06
46	Other non-metallic mineral products	4	Other non-metallic mineral products	17	0.06
47	Products of stone and soil	63	Clay and stone products	17	0.06
48	Glass products	9	Glass	17	0.06
51	Iron and non-ferrous metals	27	Basic metals	20	0.05
52	Manufacture of basic metals	22	Basic metals	20	0.05
53	Manufacture of fabricated metal products	46	Metal Products	20	0.05
54_55	Machinery and equipment	64	Machinery and Equipment	20	0.05
56_57	Electrical machinery and apparatus	43	Machinery and Equipment	20	0.05
58	Transport equipment	37	Transport	25	0.04
59	Medical, precision and optical instruments	7	Other Manufacturing	**18**	0.06
62	Conversion of buildings and auxiliary construction	1	Construction	8	0.13
63	Construction	7	Construction	8	0.13
94	Personal hygiene and cleaning, undertaking	5	Personal Services	20	0.05
95	Recreational, cultural and sporting activities	29	Health	**15**	0.07

Figure 1: Distributions of relevant input variables



IX. Appendix C

Table 11: Summary statistics

Variable	Mean	Std. Dev.
Equipment investment rate	0.0848	0.0739
Employment growth rate	0.0063	0.1537
Non-production labor growth rate	0.0152	0.1922
Production labor growth rate	0.0074	0.1824
Log Output	11.8708	1.4588
Log Labor productivity	6.9813	0.6536
Log Profits	10.6536	1.7961
Real GDP growth rate	2.6493	1.2404
Equipment investment deflator growth rate	1.8764	1.5733
Log average firm-group size	3.7102	1.4869
Log average personnel costs	5.5970	0.3584
Log non-production labor share	-0.8355	0.7146
Log gender ratio	-0.8150	1.2607

Table 12: Regression Results – fixed effects logit for all relevant observations

Independent Variables	ABSOL	REL	L-POS	L-NEG	NPL-POS	NPL-NEG	PL-POS	PL-NEG
Real GDP	0.1733 (3.39)***	0.1672 (5.61)***	0.2218 (6.26)***	-0.2299 (6.75)***	0.1503 (4.79)***	-0.1291 (4.09)***	0.1778 (5.43)***	-0.2068 (6.26)***
Deflator Equipment	0.0088 (0.25)	-0.0338 (1.66)*	-0.0808 (3.05)***	0.0846 (2.82)***	-0.0656 (2.75)***	0.0608 (2.25)**	-0.0739 (2.98)***	0.1342 (4.62)***
1st Size Quartile	-2.9586 (3.52)***	-2.6462 (5.86)***	-3.9023 (6.45)***	3.9686 (6.12)***	-2.3099 (4.70)***	3.526 (4.97)***	-3.149 (5.57)***	3.3334 (5.80)***
2nd Size Quartile	-2.4599 (3.13)***	-1.8679 (4.70)***	-2.7102 (5.00)***	3.0508 (5.14)***	-1.3934 (3.28)***	2.5259 (3.80)***	-2.5017 (4.93)***	2.7033 (5.22)***
3rd Size Quartile	-1.5831 (2.59)***	-0.7621 (2.50)**	-0.7952 (2.04)**	1.2693 (2.62)***	-0.6662 (1.97)**	1.4924 (2.51)**	-1.0352 (2.64)***	1.1251 (2.74)***
4th Size Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st PC Quartile	-0.493 (2.02)**	-0.444 (3.10)***	1.3979 (7.66)***	-1.599 (8.55)***	0.8574 (5.29)***	-0.8301 (4.92)***	1.1515 (6.77)***	-1.4326 (7.96)***
2nd PC Quartile	-0.3332 (1.64)	-0.3038 (2.58)***	0.795 (5.12)***	-1.1383 (7.53)***	0.6668 (4.97)***	-0.7593 (5.39)***	0.6132 (4.30)***	-1.0212 (7.19)***
3rd PC Quartile	-0.1946 (1.12)	-0.2092 (2.06)**	0.437 (3.17)***	-0.8832 (6.86)***	0.4159 (3.56)***	-0.6387 (5.15)***	0.3319 (2.66)***	-0.8251 (6.87)***
4th PC Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st Skill-Ratio Quartile	0.299 (1.08)	0.3586 (2.12)**	0.3806 (1.76)*	-0.6496 (3.07)***	-2.3272 (11.34)***	1.8813 (9.26)***	1.786 (8.28)***	-1.8781 (8.72)***
2nd Skill-Ratio Quartile	-0.1012 (0.41)	0.0235 (0.16)	0.2048 (1.07)	-0.3301 (1.82)*	-1.5009 (8.77)***	1.1679 (6.60)***	1.1522 (6.13)***	-1.3481 (7.48)***
3rd Skill-Ratio Quartile	-0.4033 (1.79)*	-0.099 (0.77)	0.1375 (0.83)	-0.175 (1.14)	-0.7791 (5.55)***	0.469 (3.05)***	0.7448 (4.65)***	-0.6747 (4.72)***
4th Skill-Ratio Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st Gender-Ratio Quartile	-0.5733 (1.94)*	-0.1731 (0.97)	-0.1961 (0.85)	-0.387 (1.78)*	-0.179 (0.85)	-0.2461 (1.22)	0.1361 (0.60)	-0.3308 (1.49)
2nd Gender-Ratio Quartile	-0.2262 (0.90)	-0.2377 (1.52)	0.0689 (0.36)	-0.3816 (2.03)**	0.1289 (0.73)	-0.4015 (2.25)**	0.189 (0.99)	-0.297 (1.58)
3rd Gender-Ratio Quartile	-0.1909 (0.92)	-0.095 (0.73)	0.016 (0.10)	-0.1174 (0.76)	-0.0309 (0.21)	-0.1138 (0.75)	0.1294 (0.80)	-0.0217 (0.15)
4th Gender-Ratio Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
1st Labor Productivity Quartile	0.0747 (0.27)	-0.3804 (2.39)**	0.9004 (4.51)***	-0.2399 (1.21)	0.224 (1.26)	-0.1368 (0.73)	0.5721 (2.99)***	-0.658 (3.30)***
2nd Labor Productivity Quartile	0.1298 (0.57)	-0.2045 (1.55)	0.445 (2.62)***	-0.2442 (1.46)	-0.0812 (0.54)	-0.1401 (0.90)	0.3558 (2.20)**	-0.2655 (1.63)
3rd Labor Productivity Quartile	0.1192 (0.62)	-0.1868 (1.65)*	0.3905 (2.77)***	-0.4266 (2.98)***	0.1384 (1.10)	-0.1794 (1.36)	0.4154 (3.15)***	-0.4701 (3.35)***
4th Labor Productivity Quartile	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Observations	2880	6410	4419	4312	5137	4738	4824	4746
Number of Groups	288	641	492	482	572	529	537	530
Log likelihood	-816.21	-2283.12	-1411.24	-1358.86	-1796.23	-1581.30	-1634.78	-1511.36

The dependent variable is one or zero, depending on whether between 1982 and 1991 a relative or absolute investments spike (ABSOL or REL), a positive or negative employment growth spike (L-POS or L-NEG), a positive or negative non-production labor growth spike (NPL-POS or NPL-NEG) or a positive or negative production labor spike (PL-POS or PL-NEG) has occurred. The independent variables included represent quartiles of size, personnel costs, non-production labor shares, gender-ratios and labor productivity. To account for firm heterogeneity, i.e. unobservable and time-invariant firm characteristics, fixed as well as random effects logit models were calculated. The Hausman tests clearly reject suitability of the random effects logit specification so results are presented for the fixed effects logit specification only.

Estimated results are presented for all available data and not limited to the three-year window applied in section II.

Absolute values of z-statistics are in parentheses.

*Significant at 10 % level.

** Significant at 5 % level.

*** Significant at 1 % level.