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LABOR ADJUSTMENT, PRODUCTIVITY AND OUTPUT VOLATILITY: AN EVALUATION OF JAPAN'S EMPLOYMENT ADJUSTMENT SUBSIDY

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Abstract

This paper provides a theoretical examination of the impact of Japan's Employment Adjustment Subsidy, a major employment insurance policy since 1975, on labor adjustment, productivity and output fluctuations in the iron and steel sector. A partial equilibrium industry model with heterogeneous establishments and aggregate uncertainty shows that the EAS reduces steady-state labor productivity by encouraging labor hoarding, while reducing job flows and increasing average firm-level employment. While the directly measured impact on productivity is proportional to the fraction of subsidized workers, the indirect effects of the subsidy on output and employment volatility can be substantially larger. First, the subsidy can lead to a sizable increase in output fluctuations over business cycles by symmetrically increasing the output response to shocks. This result is achieved through lower output via subsidy during unfavorable aggregate shocks and higher output via less spending on hiring during favorable aggregate shocks. Second, the subsidy meets its primary objective of reduced employment volatility. The reduction can be considerable when hiring and firing costs are set equal to the annual wage.

Journal of Economic Literature Classification Numbers: D21, E32, E37, L16.
Key Words: Employment policy, productivity, output volatility, business cycle, job creation and destruction.

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1 Introduction

This paper examines the Employment Adjustment Subsidy (EAS), a core Japanese employment insurance policy since 1975.[1] The EAS program allows firms to reduce output during unfavorable business conditions without laying off workers by providing part of the costs of sustaining excess workers.[2] The EAS policy has not yet been formally analyzed despite recent macroeconomic literature emphasizing job reallocation as a driving force behind business cycles. Therefore, the primary objective of this paper is to point out some of the key implications of the policy through the application of a theoretical framework of heterogeneous establishments with aggregate uncertainty. In particular, this paper investigates the impact of the EAS on average labor productivity, job flows and entry/exit rates at the steady-state. In addition, it examines the implications of the policy for the volatility of employment, output and productivity over business cycles.

Between 1990 and 2002, more than 360 billion yen (over 3.6 billion US dollars) was spent on the EAS. On average between January 1991 and October 2001, about 170,000 establishments were eligible for the subsidy program.[3] According to the *1996 Establishment Census*, there are about 6.5 million establishments in Japan (excluding public service) with 770,000 in manufacturing. Thus, the average number of targeted establishments corresponds

[1] I wish to thank John Haltiwanger, John Shea, Michael Pries, Jeffery Smith, Katherine Abraham, Akie Takeuchi, Ana Maria Oviedo, and Kazuhiko Odaki for their comments and invaluable suggestions, Kyoji Fukao for providing the JIP database, and Employment Security Bureau of Japanese Ministry of Health, Labor and Welfare for preparing the EAS information.

[2] Since 1975, the employment insurance programs had three central interrelated projects: (1) *an employment stabilization project* that was carried out through the Employment Adjustment Subsidy, (2) *a skill development project* providing assistance to the management and development of job training centers, and (3) *a workers' welfare project* providing employment consultation. The employment stabilization project has been the most predominant of the three.

[3] As described later in this paper, additional criteria set by the government in terms of past employment and output trends must be satisfied in order to receive the subsidy.

to 2.6% of the total number of establishments, or approximately 20% of manufacturing establishments. The number of targeted establishments peaked at 411,000 units in February 2000.

The EAS recipients are heavily concentrated in the manufacturing sector, with the largest beneficiary being the iron and steel industry. The manufacturing sector and the iron and steel industry, respectively, received approximately 94% and 40% of the total subsidy bill between 1990 and 2002.[4] Although the program in principle involves the entire economy, to illustrate the theoretical implications of the program, this paper focuses on the iron and steel industry. The calibrated industry model developed later will attempt to match key moments obtained from the data for this industry.

With respect to the empirical background, Davis and Haltiwanger (1990, 1992, 1999) and Davis, Haltiwanger and Schuh (1996), using longitudinal data sets in the US manufacturing sector, expose the importance of idiosyncratic differences across establishments in explaining business cycle dynamics. Many theoretical frameworks analyzing industry dynamics, such as Jovanovic (1982), Hopenhayn (1992), Hopenhayn and Rogerson (1993), Ericson and Pakes (1995) and Campbell and Fisher (2000), also stress the importance of heterogeneity across firms when characterizing firm's production and entry/exit decisions. To the extent that the EAS interacts with such heterogeneity across establishments within an industry, the appro-

[4] In October 2001, the Japanese government abolished industry selection completely in response to criticism that the program was skewed toward particular industries: the current guidelines provide that any establishment can receive the subsidy if specific and much stricter criteria are satisfied. Namely, the monthly average of the last *six* months' production has to drop by more than 10% and employment has to be less than or equal to, in comparison with the same months of the previous year. Previously, the monthly average of the last *three* months' production had to be strictly less, while employment had to be equal or less than the previous year. Furthermore, the subsidy cannot be given to establishments whose unfavorable business conditions are predicted to last for more than two years, and establishments are no longer able to receive the subsidy continuously for more than a year. Instead, they are required to take a year long hiatus, except during severe economic circumstances.

priate theoretical framework to analyze the effect of the policy must also encompass similar features.

In addition, prior research concerning the implications of differing labor market institutions, particularly European employment policies, has shown that labor market policies have an important effect on equilibrium job flows, unemployment and productivity. Hopenhayn and Rogerson (1993), for instance, illustrate that high firing costs in Europe, which interfere with the process of job reallocation, lead to a sizable reduction in employment and a drop in average productivity. Others have stressed the interactions between a changing economic environment and labor market policy. Ljungqvist and Sargent (1998) explain that generous unemployment benefits increase unemployment rates when the skill mix demanded in the labor market is rapidly changing. Other studies have linked multiple labor market policies. Bentola and Rogerson (1993), for example, demonstrate that wage compression in Europe tends to generate more volatile employment flows, fostering a policy that restricts the firing of workers. They argue that these institutional differences can account for the similarities in job flows and differences in unemployment between Europe and the US. Even though this paper will not examine the political economy of the origin of the EAS, one of the chief objectives of the EAS has been to reduce the volatility of employment.

As wage compression can be considered as a precondition for firing restrictions, some labor market institutions, namely labor adjustment costs and wage rigidities, are likely preconditions for the EAS, since the subsidy will not be used if labor adjustment is costless or if wages can absorb shocks. Despite the fact that there are few quantitative studies that estimate the cost of firing workers in Japan, there is some legal evidence that suggests that firing workers in Japan is generally very difficult, more similar to the European than the US case.[5] Moreover, the post-war tradition of life-time employment has encouraged firms to invest in building firm specific human capital.[6] This evidence indicates that adjusting employment has been quite costly in Japan. Correspondingly, the EAS was designed in order to "assist firms in their efforts to maintain employment in times of temporary unfavorable business conditions owing to economic recession or changes in the industrial structure of the Japanese economy, as well as to promote employment stability and prevent unemployment."[7]

While there has not been a formal empirical study on the effect of the subsidy program, primarily due to the unavailability of data, some existing studies suggest that the EAS distorts employment behavior. For instance, Hashimoto (1993) uses monthly aggregate manufacturing data and finds that, since the subsidy allows for adjustment through temporary business closures, employment became less sensitive, while working hours became more sensitive, to demand shocks after the subsidy program was enacted in 1975.[8] While factors other than the EAS may be part of his results, the estimated elasticity of employment with respect to unanticipated demand shocks drops dramatically from .30 before (1967-74) to -.27 (1975-86) after the initiation of the EAS policy. Likewise, the estimated elasticity of employment with respect to anticipated demand shocks falls from .28 to -.27. These coefficients are significant in all cases. He also points out that the treatment of temporarily laid off workers in Japanese

[5] Takashi Araki (2000) discusses the legal evidence of stringent firing restrictions in Japan from the perspective of corporate governance.

[6] A detailed discussion of the relationship between intensive human capital investment and the low turnover rate in Japan is provided by Mincer and Higuchi (1988).

[7] Japanese Ministry of Health, Labor and Welfare. "Guidebook for Employment Adjustment Subsidy," 2002.

[8] On the contrary, the unemployment insurance (UI) system in the US encourages temporary layoffs instead of temporary business closures. Feldstein (1976, 1978) and Anderson and Meyer (1993) discuss the incentive for firms to increase temporary layoffs when the experience rating of firms' unemployment insurance is imperfect. Feldstein (1976) explains why employment instead of hours is reduced in response to negative demand shocks under the UI system in the US.

statistics as 'employed' explains part of the differences in unemployment rates between Japan and the US.

Another related yet unexplored empirical issue is that the presence of subsidized workers reduces measured productivity, since hoarded workers are not properly taken into account in employment statistics. This paper will attempt to estimate the number of unutilized workers through the subsidy program in the iron and steel industry, as well as the reduction in productivity that can be accounted for by the inclusion of subsidized workers in employment statistics. Then, these estimates will subsequently be used for the calibration of the model. The model developed here offers insights beyond the direct effect of labor hoarding on productivity. The indirect effects of the EAS on the cyclical dynamics of output and employment generate a wide set of empirical predictions, testable in future research as more data becomes available.

The model exploits the theoretical framework of Hopenhayn (1992) and Hopenhayn and Rogerson (1993). The main advantage of using their framework is is that, as previously mentioned, their model allows for a heterogeneity across establishments and thus allows us to evaluate the impact of the subsidy program on industry dynamics by explicitly modeling the equilibrium response of heterogeneous establishments. Unlike Hopenhayn and Rogerson, however, the consideration of labor supply decisions and hence the households' problem will be omitted to focus on the impact of the subsidy on establishment-level dynamics. Thus, the analysis will be a partial equilibrium estimate of the change in overall industry dynamics caused by the subsidy program. Moreover, two-state aggregate uncertainty is added to the model, a feature that was not present in Hopenhayn and Rogerson (1993). Since the wage remains constant in the model, the aggregate uncertainty should be best interpreted as reflecting the partial equilibrium real impact of shocks net of their impact on wages.

In interpreting the impact of the subsidy on average labor productivity, a word of caution is in order: while firms are heterogeneous in the model, workers are homogeneous in the sense that productivity does not increase with tenure. The subsidy could increase average productivity if this feature were added to the model. This feature was not added in the model because of the high concentration of the subsidy in sectors where the value of workers' skills seems to be depreciating faster in comparison to other sectors.[9] In my model, the difference between old and new workers is solely reflected in the hiring cost, which reduces output during the first period; the productivity of new and old workers is equalized afterwards.

I show that the subsidy program reduces steady-state average productivity primarily by increasing the number of unutilized workers (labor hoarding effect). Roughly speaking, the reduction in average productivity is more or less proportional to the fraction of subsidized workers: when the fraction of subsidized workers is about 1%, average productivity also falls by roughly the same amount. At the same time, average firm-level employment increases and the job turnover rate falls with the subsidy. When the cost of the subsidy and the gains of reduced adjustment costs are included in the calculation of average productivity, productivity is further reduced for reasonably sized labor adjustment costs, as the cost of the subsidy exceeds the savings on labor adjustment costs.[10]

The estimated direct impact of the subsidy on productivity is small, as the estimated average fraction of subsidized workers in the iron and steel sector between 1990 and 2002 is

[9]For example, the subsidy seemed to have concentrated in those sectors with comparative disadvantage in the international market. The government often cites as reason for industry selection into the EAS as "unfavorable business conditions arising from the competition with cheaper imports from China" etc.

[10]However, with high enough labor adjustment costs, it is possible that the savings on adjustment costs could exceed the cost of the subsidy.

about 2.1%. Novertheless, the second moment features generated by my simulation exercises reveal that with realistic parameters, the subsidy program has a disproportionately large impact on output and employment dynamics over the business cycle. In particular, output volatility can increase by 3.5% even when the steady-state fraction of subsidized workers is around 1.6%. The intuitive reason for this result is that the subsidy increases the sensitivity of output to aggregate shocks symmetrically: following unfavorable shocks, the subsidy allows firms to reduce production without laying off workers, while following favorable shocks, firms are able to increase output without hiring new workers.

On the other hand, the subsidy reduces employment volatility. In some cases, the drop in employment volatility can be substantial, even when the fraction of subsidized workers is small. Below, I show that hiring and firing costs set equal to the annual wage of workers can reduce the volatility of employment by about 12% even if the fraction of subsidized workers is less than 2%. The reduction in employment volatility is achieved by the reduced sensitivity of job creation and destruction to aggregate shocks over the business cycle. The EAS also increases the average size of the firm while reducing average firm level output at the steady-state. Finally, the steady-state exit/entry rate as well as the steady-state job creation/destruction rate drop with the subsidy.

This paper proceeds as follows: section (2) provides a brief background of the EAS as well as an overview of the employment and output trends obtained from the aggregate iron and steel industry data. I then calculate the direct impact of the EAS on TFP induced by labor hoarding, which later will be used for the calibration of the model. Section (3) lays out the theoretical framework of the industry model and provides analytical results. Section (4) shows results from solving a stochastic version of the model through numerical dynamic programming. I present key statistical features obtained from the stationary distribution of the model as well as simulation exercises, and compare the subsidy case with the benchmark case that sets the subsidy to zero. Section (5) concludes.

2 Background

2.1 Summary of the EAS

The Employment Adjustment Subsidy program was initiated in 1975 as a preemptive measure against unemployment. More specifically, it was initiated in response to policy-makers' concern that the unemployment rate would rise following the first oil shock and the resulting changes in the industrial structure of the Japanese economy.[11] In principle, however, the subsidy was designed to help sustain employment during "temporary unfavorable business conditions" without incurring the loss associated with labor adjustment costs.[12] This objective was mainly achieved by reimbursing a fraction of wages for establishments closing part or all of its operations, or a fraction of the cost of sending workers to other (unrelated) establishments. The subsidy was expected to lower unemployment as well as the cost of unemployment insurance by reducing the unemployment rate.

Prior to 2001, the government selected eligible industries, either entire four-digit sectors or subsectors, based on recent trends in industrial output and employment, or changes in

[11] The Japanese Ministry of Labor reports that the EAS was originally designed in response to a recommendation by the OECD that the Japanese government prepare for higher unemployment arising from the transition from a growing to a mature economy. [Japanese Ministry of Labor, Employment Security Bureau (1999), p. 14.] Another justification often provided was to assist firms, which had been the primary provider of job security often in the form of life-time employment, to sustain employment during difficult times.

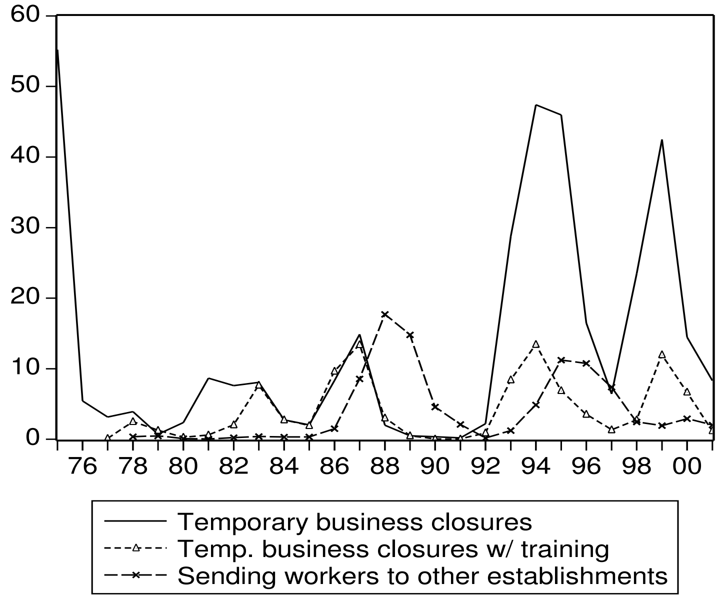
[12] While the government preferred to consider the subsidy as a "temporary" assistance measure designed to reduce the severe negative impact of sectoral shocks on unemployment, in practice, some industries facing long-term structural changes were often able to maintain eligibility for an extended period of time.

the industrial structure, such as rising competition from foreign imports. The official selection criteria in terms of output and employment were: i) the average of the past three months' industrial production dropped more than 5% compared to the same months of the previous year, and ii) the average of the past three months' employment had not increased compared to the same months of the previous year.[13] Furthermore, additional special selection criteria were set in 1995 for more generous subsidy coverage: "as a result of an appreciation of the yen or economic globalization, the monthly average of the past six months' industrial production and employment fell or is predicted to fall more than 10% compared to the same season in one of the three previous years." The selection was not completely deterministic as explained by the government: the "selection is not solely based on figures but also determined in accordance with our objective of the prevention of unemployment."[14] The Japanese government abolished industry selection criteria in October 2001, replacing them with tougher establishment-level eligibility criteria.

Under the standard selection rules, industries were selected for one year with the possibility of an extension for an extra year if needed. Once selected, industries could be reselected after a six-month break. For the special selection rules between 1995 and 2001, the selection period was set to two years with the possibility of an extension. Between 1990 and 2001, the unweighted average length of eligibility for a selected industry was 2.6 years with a maximum of 7 years. During the same period, about 96% of the selected four-digit industries or subcategories belonged to the manufacturing sector, of which about 14% belonged to ceramic and clay products, 13% to general machinery, 10% to metal products, 10% to textiles

[13]As for the employment criteria, it became 'a drop of 5% or more' between March 2000 and October 2001.
[14]Japanese Ministry Labor, Employment Security Bureau (1999), p. 191.

Figure 1: Annual Total Subsidy Bill (in billions of yen) for 1975−2001



Source: Employment Security Bureau of Japanese Ministry of Health, Labor and Welfare.

and 9% to the iron and steel industry.

Once an industry was selected, establishments in this industry, as well as their upstream suppliers, could take up the subsidy if the average of their last three months' production (employment) was less (equal or less) than the monthly average for the same season a year before. Small- and medium-size establishments meeting these criteria could receive 2/3 of their labor costs (3/4 under special selection) and large establishments could receive 1/2 of their labor costs (2/3 under special selection) while they implemented temporary closures of their business operations.[15] Additional allowances of three thousand yen per worker per day were

[15]Note that establishments do not have to pay full wages while they implement temporary business closures. Moreover, the maximum coverage for the establishments in an industry selected under standard selection criteria (*shitei-gyosyu*) was 100 days $\times$ the total number of employees, and the maximum coverage for firms in a industry selected under the special selection criteria (*tokutei koyo chosei gyosyu*) was 200 days $\times$ the total number of employees. Between July 1995 and October 2000, about 44% of the targeted establishments could apply under the special selection criteria.

given if establishments provided job training to workers while they temporarily closed their businesses.[16] Instead of business closures, establishments could also send workers to other unrelated establishments for more than three months. In this case, the receiving establishment was required to pay for the labor service provided by the subsidized workers, and the sending establishment paid the difference between the workers' original wage and the amount paid by the receiving establishment. The subsidy covered a fraction of the cost borne by sending establishments.

Although the subsidy program started in 1975, its effect was probably largest during the 1990s, the decade of sluggish growth. Figure 1 shows the subsidy bill for each of the three options available to establishments. The total subsidy bill dramatically increased after 1992. Furthermore, among the three options, temporary business closure had the highest share of the total subsidy bill, especially during the 1990s. Subsequently, the analysis of this paper focuses on the 1990s for the following reasons: i) more establishments were made eligible during the 1990s, ii) the subsidy rules stabilized by 1990, and iii) data on the subsidy bill by two-digit sector is available only after 1990. In the theoretical section, I will model the policy using the criteria prior to the October 2001 revision.

The share of the total subsidy bill between 1990 and 2002 as well as the annual average share by two-digit sector is provided in Table 1.[17] The iron and steel industry has the largest annual average share (47.03%), followed by general machinery (10.49%), transportation equipment (8.15%), and textiles (4.93%).[18] As mentioned previously, the high

[16]In October 2001, however, the allowance for training was reduced to 1200 yen.

[17]This data was made available upon request from Employment Stability Bureau of Ministry of Health, Labor and Welfare.

[18]The share calculated is in terms of annual average. The results for the total subsidy bill between 1990 and 2002 are similar.

Table 1: Share of Subsidy Bill by Industries for 1990−2002

	Total Bill	Annual Average
Manufacturing Total	93.96%	93.45%
Food	0.09%	0.13%
Beverage, feed and tobacco	0.04%	0.03%
Textiles	5.31%	4.93%
Apparel and other textiles	1.74%	1.53%
Lumber and wood products	0.63%	0.59%
Furniture and fixtures	0.64%	0.59%
Pulp and paper products	0.44%	0.26%
Printing and publishing	0.03%	0.03%
Chemical and allied products	1.54%	1.28%
Petroleum and coal products	0.15%	0.15%
Plastics	0.54%	0.38%
Rubber products	1.40%	1.13%
Leather, tanning, fur products	0.19%	0.17%
Ceramic, stone and clay products	3.98%	3.52%
Iron and steel	40.70%	47.03%
Non-ferrous metals	1.61%	1.42%
Fabricated metals	3.36%	2.78%
General machinery	12.75%	10.49%
Electrical machinery	6.24%	7.21%
Transportation equipment	10.69%	8.15%
Precision instruments	1.06%	0.96%
Ordinance	0.03%	0.02%
Other manufacturing	0.80%	0.67%
Other Sector Total	6.04%	6.55%

Source: Employment Security Bureau of Japanese Ministry of Health, Labor and Welfare.

concentration in the iron and steel industry motivates my modeling the effects of the subsidy program on this industry.[19]

[19] A strong union presence, which generates wage rigidity and high labor adjustment costs, may be one of the reasons why the iron and steel industry has a high take-up rate. Yet, since eligible industries are given by four-digit industries or subcategories within four-digit industries while the estimated number of subsidized workers are available by two-digit industries, the investigation of the take-up rates across sectors requires the size of eligible workers to be estimated by two-digit industries. This estimation was not done in this paper and remains an area for future research.

2.2 Overview of the Iron and Steel Industry

This section provides an overview of output, employment and productivity behavior in the iron and steel industry between 1973 and 2001. The data set used to study output is the *Japan Industry Productivity Database* (JIP database).[20] This data set was compiled as a part of the Japanese government's project to calculate annual TFP for 84 sectors in Japan between 1973 and 1998.[21] Since the database is based on the 1968 SNA (System of National Account), currently data is available only through 1998. Figure 2 shows real gross output between 1973 and 1998. There is a considerable increase in output in the late 1980s and early 1990s, followed by a large drop in the mid- and late-1990s. Figure 3 shows the employment trend, taken from the *Employment Trend Survey,* which includes both permanent and temporary workers for all establishments with more than five employees.[22] Except in the mid-1980s, employment exhibits a steady decline since 1973. This fact, combined with the positive trend in real gross output implies increased capital intensity or TFP during this period.

If subsidized workers are included in employment, then standard productivity measures will be distorted since labor input will be systematically overstated.[23] The data provides the annual subsidy bill by two-digit sector between 1990 and 2002, but does not provide the total number of subsidized work days in each sector. Consequently, we need to estimate the number of unutilized workers for each year using the annual subsidy bill. This estimation was accomplished as follows: first, the average subsidy cost per work day (i.e., per worker

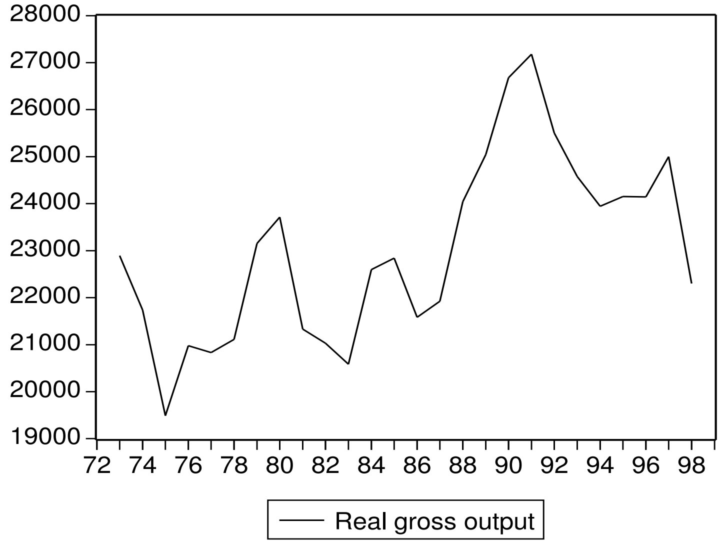
[20] The JIP database is made available in English by Kyoji Fukao on his website: http://www.ier.hit-u.ac.jp/~fukao/english/data/index.html.

[21] See Fukao et al. (2003) for the TFP analysis of the 84 sectors from 1973 to 1998 using the JIP database.

[22] The beginning-of-year (January 1) figure was used to represent the employment of the previous year.

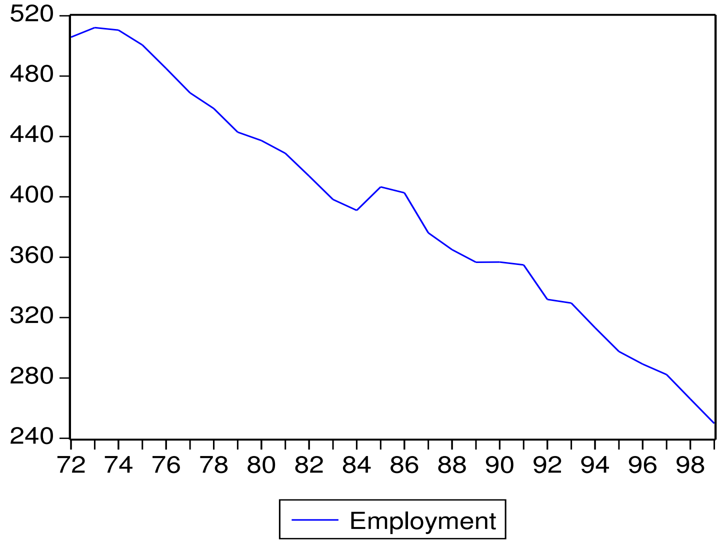
[23] Note that average work hours may capture part of labor hoarding through the EAS, but it is unlikely to entirely capture the total number of subsidized workers. For the discussion of variable factor utilization in affecting cyclicality of productivity, see Basu and Kimball (1997), Basu and Fernald (2000) and Basu, Fernald and Shapiro (2001).

Figure 2: Real Gross Output in the Iron and Steel Industry (in billions of yen)



Source: JIP database.

Figure 3: Annual Employment in the Iron and Steel Industry (in thousands)



Source: *Employment Trend Survey.*
Note: The figure includes both permanent and temporary workers for all establishments with more than five employees.

per day) was calculated by dividing the total subsidy bill covering the entire economy by the total number of subsidized work days covered each year.[24] Then, the annual subsidy bill for the iron and steel industry was divided by the annual average subsidy cost per work day in order to calculate the total number of subsidized days in this industry. Finally, this number was divided by the annual average work days for workers in the iron and steel industry to get an estimate of the number of subsidized workers for each year.[25] Figure 4 shows the result of this calculation. On average, 2.1% of iron and steel workers were subsidized during this period. In 1995, the highest take-up year, 4.6% of iron and steel workers were subsidized.[26]

Since the JIP dataset ends in 1998, an alternative source of output data must be used to calculate productivity between 1990 and 2001. I use measures of real value added as well as capital stock, both based on the 1993 SNA standard, from the *Annual Report on National Account*.[27] An annual growth accounting exercise, as in Hayashi and Prescott (2000), was performed to estimate the level as well as the growth rate of TFP both before and after adjusting labor inputs for the number of subsidized workers. More specifically, I adopt the following Cobb-Douglas specification:

$$Y = AK^{\theta}(h \cdot (E - S))^{1-\theta}, \tag{1}$$

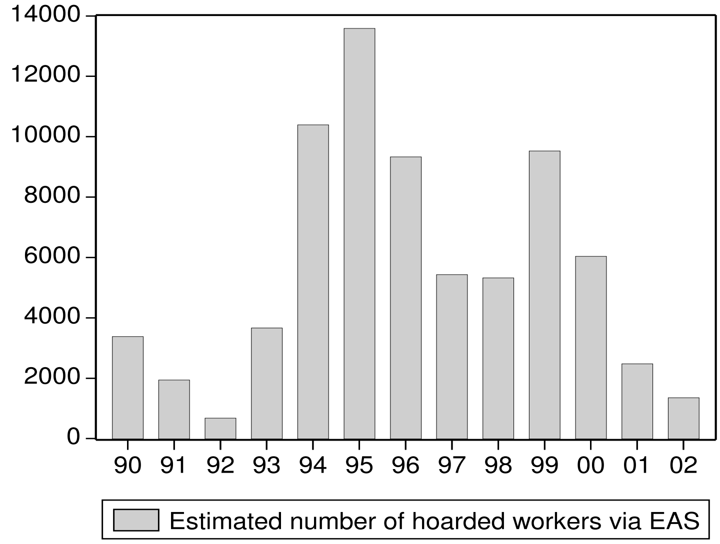
[24] Since there are three subsidy options (i.e., temporary closures, temporary closures with training, and sending workers to other establishments), the weighted average of these three was taken to estimate the average cost per work day. Since the workday cost for sending workers to other establishments cannot be estimated, this cost was replaced by the work day cost of temporary closures.

[25] The average work days for workers in the iron and steel industry was taken from *Monthly Labor Statistics* by the Japanese Ministry of Health, Labor and Welfare. Since the figure provided here is the monthly average, it was multiplied by 12 to get an approximate annual figure. The data is available at the following website in Japanese: http://stat.jil.go.jp.

[26] However, since the subsidy bill includes the third option, namely 'sending workers to other establishments,' if we focus only on temporary business closures given by the first two options, the estimated average fraction of workers should be somewhat smaller than 2.1%.

[27] Capital stock is at completion basis. The data can be found at the following website in Japanese: http://www.esri.cao.go.jp/jp/sna/toukei.html.

Figure 4: Estimated Hoarded Workers via EAS in the Iron and Steel Industry



Source: Subsidy information was provided by Employment Security Bureau of Japanese Ministry of Health, Labor and Welfare. Other data used for the estimation is provided in the text.

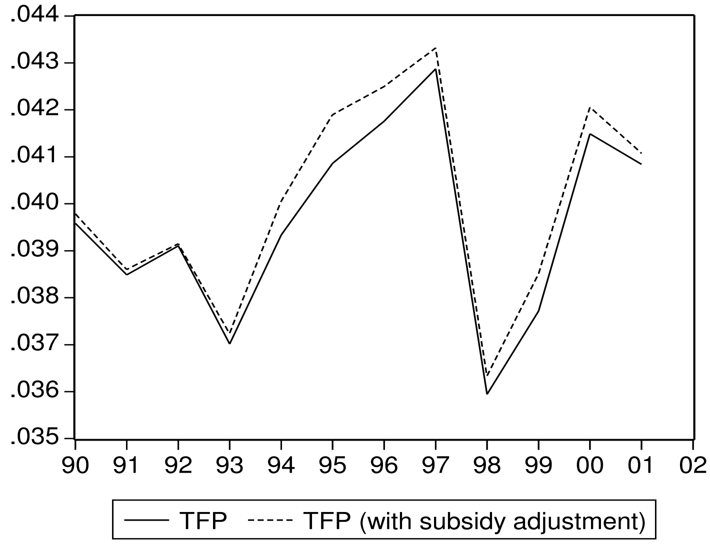
where Y is real value added, A is the measure of TFP, K is the real capital stock, h is average work hours, E is employment and S is the number of subsidized workers.[28] The cost share of capital θ is set equal to 0.464, which corresponds to the average cost share of capital excluding material inputs between 1973 and 1998 given by the JIP database.[29]

Figure 5 shows the level of TFP in the iron and steel industry with and without adjustments for the subsidy, using the National Accounts data. The level of TFP is higher when employment is adjusted for the subsidy for obvious reasons. The adjustment is the highest in 1995 in which adjusted TFP is higher than unadjusted TFP by 2.53%. On average, adjusted TFP is higher by 1.15% between 1990 and 2001.

[28]The average work hours was taken from *Monthly Labor Statistics* by the Japanese Ministry of Health, Labor and Welfare, and employment data is taken from the *Employment Trend Survey.* Note that the employment figure is based on establishments with more than 5 employees, while the work hour figure is based on establishments with more than 30 employees, due to the lack of series since 1975.

[29]In aggregating the cost share at the two-digit level with the JIP dataset, nominal gross output was used as a weight because the dataset does not provide the total cost for each sector.

Figure 5: TFP (1990−2001) in the Iron and Steel Industry



Source: *Annual Report on National Account* for the output and capital stock, *Employment Trend Survey* for annual employment, and *Monthly Labor Statistics* for average work hours. See the text for the estimated annual number of subsidized workers.

The same exercise was done using the JIP database, in order to evaluate how much this adjustment reduces the procyclicality of TFP. Note that since the subsidy bill by industry is not available before 1990, the number of subsidized workers prior to 1990 is estimated by applying iron and steel's average annual share of 47% between 1990 and 2002 to the total subsidy bill. While not shown here, the two measures of TFP are almost identical except during the 1990s. The correlation between the log of TFP and the log real gross output falls from 0.7916 to 0.7843 when the subsidy adjustment is made, and the correlation between the log of TFP and the log real value added falls from 0.9921 to 0.9906. The correlation between the log real gross output and the log subsidy bill is -0.645. The result is consistent with the argument that labor hoarding via EAS increases the procyclicality of productivity, although only a small part is accounted for by the subsidy.[30]

The exercise in this section reveals that the subsidy, due to the small fraction of subsidized workers, has a trivial impact on the level and procyclicality of TFP. The calibrated model in the next section will attempt to match these moments to investigate the impact of the subsidy program. I will show later that even when the direct impact is small, the EAS can have a significant impact on output and employment volatility.

3 An Industry Model

In this section, I build a simple industry model to capture the effect of the employment subsidy. Let n_t denote the total number of employees in the firm and $e_t \leq n_t$ the number of workers who are utilized for production at period t. The firm needs to pay a wage equal to w to each of the e_t workers who actually work and produce, and a fraction γ of w to the $n_t - e_t$ workers who are unutilized for production. Firms are eligible for the subsidy with probability π. If eligible, they can receive payments for their $n_t - e_t$ unutilized workers. Let s denote the fraction of the labor cost of unutilized workers that the government subsidizes. That is, for each unutilized worker, the government pays a fraction s of the discounted wage γw that unutilized workers receive, and the remaining $(1-s)\gamma w$ is paid by the firm. Hence, the total subsidy received by a firm at time t when subsidized is given by $(n_t - e_t)\gamma ws$.[31] Total employment n_t will be the state variable that firms carry to the next period, unless they decide

[30] In terms of growth rate, the correlation between the TFP growth rate and the growth rate of value added falls from 0.9929 to 0.9879. The same exercise using National Accounts data shows that the correlation between the log of TFP and the log real value added falls from 0.435 to 0.396, and the correlation between the log real value added and the log subsidy bill is -0.244. Nonetheless, with this data, significance levels are low due to a small number of observations.

[31] Note that the government provides a guideline on γ, but the consent of the workers is required (typically through an agreement with their labor union) for them to miss work at a discounted wage γw.

to exit the market.

Firms have a stochastic production function $f(e_t, \varepsilon_t)$, use labor as the only input of production and receive a profitability shock, denoted as ε_t, that has an idiosyncratic component as well as an aggregate component common to all firms. The production function is assumed to be strictly concave in labor and satisfies $f_e > 0$ and $f_{ee} < 0$. Moreover, the wage and price are both assumed to be exogenously determined and invariant over time. For a given price p, the expected profits for a firm that employs n_t workers, utilizes e_t workers for production, takes up the subsidy if available, and receives a shock ε_t at period t are as follows:

$$pf(e_t, \varepsilon_t) - we_t - \gamma w(n_t - e_t) + \chi_t(n_t - e_t)\gamma ws - pc_f - \psi(n_t, n_{t-1}) - \phi(n_t, n_{t-1}). \qquad (2)$$

The first term is revenue from output. The second and third represent wage payments to utilized and unutilized workers respectively. The fourth captures the subsidy receipts. Here, χ_t is a random variable that takes a value of 1 with probability π and 0 with probability $1 - \pi$. The term pc_f reflects the fixed costs of production each period and can be interpreted as the opportunity cost of the entrepreneur. This fixed cost provides firms incentives to exit the market when their prospects look sufficiently unfavorable, instead of simply waiting for their future prospects to turn around. As described in Hopenhayn and Rogerson (1993), this term is necessary for some positive amount of exit to exist in equilibrium. In what follows, p will be set as a numeraire so that it will not show for the rest of the analysis.

The terms $\psi(n_t, n_{t-1})$ and $\phi(n_t, n_{t-1})$ represent linear hiring and firing costs respectively, and are specified as:

$$\psi(n_t, n_{t-1}) = \tau_h \cdot \max(0, n_t - n_{t-1}) \tag{3}$$

$$\phi(n_t, n_{t-1}) = \tau_f \cdot \max(0, n_{t-1} - n_t) \tag{4}$$

where τ_h and τ_f are the fixed costs of hiring and firing a worker. Either τ_h or τ_f must be positive in order to provide firms incentives to take up the subsidy, since without labor adjustment costs, labor adjustment is always instantaneous and there is no need to keep excess workers when firms receive unfavorable shocks.

The timing of decisions is given as follows. An incumbent starts t with previous period's shock ε_{t-1} and previous period's employment n_{t-1}. Before observing its current profitability shock and subsidy eligibility, a firm must decide whether to shut down or stay in business based on its expected profitability. If the firm decides to exit its business, the workers will be dismissed entirely and the firm must pay the firing cost to each of its workers, while avoiding the fixed cost of operation c_f.[32] It then receives zero profits in all future periods. If the firm decides to stay, the incumbent firm observes current profitability ε_t and subsidy eligibility χ_t, and it decides whether to take up the subsidy or not if $\chi_t = 1$. Subsequently, it chooses employment n_t and the number of utilized workers e_t, and produces with $e_t < n_t$ with the subsidy or $e_t \leq n_t$ without the subsidy, before moving to the next period with n_t. Here, I do not impose the constraint $e_t = n_t$ when firms are not subsidized, although this equality will hold at an optimum for the set of parameter values provided in the next section.

The value function for firms under this policy scheme is given by the following equa-

[32] Alternatively, this sequence of timing implies that at the beginning of the period when the current state is revealed to the firm, it decides whether or not it exits from the market at the end of the period.

tion:

$$
\begin{aligned}
V(n_{t-1},\varepsilon_t,\chi_t) = \max_{e_t \le n_t, n_t} \{ & f(e_t,\varepsilon_t) - we_t - \gamma w(n_t - e_t) + \chi_t(n_t - e_t)\gamma ws - c_f \\
& - \psi(n_t,n_{t-1}) - \phi(n_t,n_{t-1}) + \beta\{ \max_{\text{stay, exit}} [EV(n_t,\varepsilon_{t+1},\chi_{t+1}), -\phi(0,n_t)]\}\},
\end{aligned} \tag{5}
$$

where $e_t = n_t$ if the firm fully utilizes all its workers. The first order conditions of the value function with respect to e_t and n_t imply that the optimal level of e_t is driven by the current shock ε_t and parameters such as s, w, and γ, while the optimal n_t is affected by w, s, τ_h, τ_f and the expected marginal future benefit of the extra worker. This result implies that the decision to take up the subsidy will depend not only on the size of the subsidy and labor adjustment costs, but also on how unfavorable today's shock looks relative to future prospects.

Two additional intuitive implications of the subsidy program are the following. The first is that an increase in the volatility of aggregate and/or idiosyncratic shocks, as well as a reduction in the persistence of shocks, increases subsidy take-up by reducing optimal utilization beneath the optimal level of employment when a firm receives a temporary unfavorable shock.[33] The second is that a subsidized firm keeps the level of employment higher, and output lower, in comparison with a non-eligible firm with the same previous level of employment and current profitability conditions. An analytic explanation will be provided shortly.

For a given set of parameter values, the state variables n_{t-1}, ε_t and χ_t affect firms' decisions regarding employment, production and subsidy decisions. First, I will provide a graphical explanation of the state spaces over n_{t-1} and ε_t for which subsidy take-up takes place given eligibility. Then using the first order conditions, I will show the marginal change

[33]The results obtained from a numerical experiment is available upon request from the author.

that eligibility generates by comparing the behavior of eligible and non-eligible firms facing the same state condition (i.e., n_{t-1} and ε_t), assuming that the eligible firm finds it optimal to take up the subsidy.

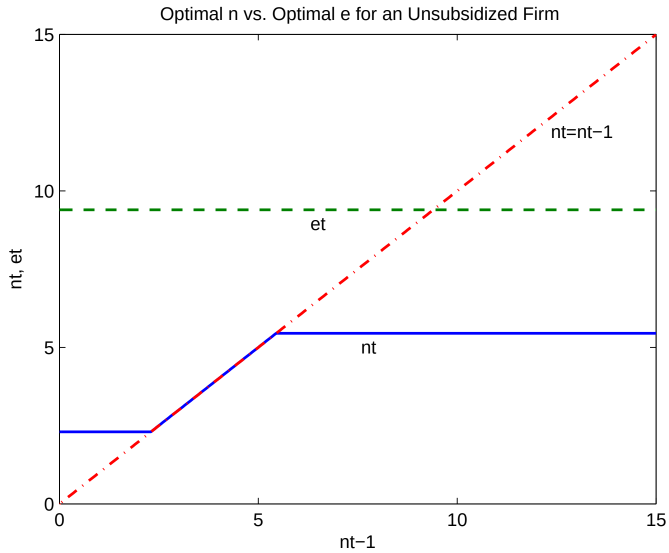
Ignoring the constraint $e_t \leq n_t$, consider a case in which a firm receives a temporarily favorable shock. Figure 6 illustrates the optimal employment and production decision rules for this case. Regarding the optimal choice of n_t, notice that it features a region of inaction owing to the presence of labor adjustment costs. The dotted diagonal line represents the points where $n_t = n_{t-1}$. The firm expands in employment size when n_{t-1} is such that the optimal n_t lays above the dotted line, and it contracts if n_t lays below the dotted line. Where the two lines overlap, the figure shows the region of inaction.

On the other hand, the optimal choice of e_t is independent of the state variable n_{t-1}. Since firms in this case are having a temporary favorable shock, the e_t dictated by the optimal current production decision will be higher than n_t driven by the future prospect of profitability. As a consequence, we have an infeasible situation in which the unconstrained optimal e_t is higher than n_t, as illustrated by Figure 6. Obviously, no firm can take up the subsidy under this scenario.

Note that smaller firms that are expanding are unlikely to take up the subsidy. This intuition is given by the fact that labor hoarding is costly even when firms receive a subsidy. Numerical exercises also show that, for the parameter values provided in the next section, firms do not apply at an optimum when they are expanding. Thus, I simply assume here that no subsidy take-up takes place when the state variable n_{t-1} is such that the optimal n_t lays above the dotted diagonal line.

Next, consider a case in which a firm experiences a temporarily unfavorable shock.

Figure 6: Employment and Production Decision Rule for an Unsubsidized Firm

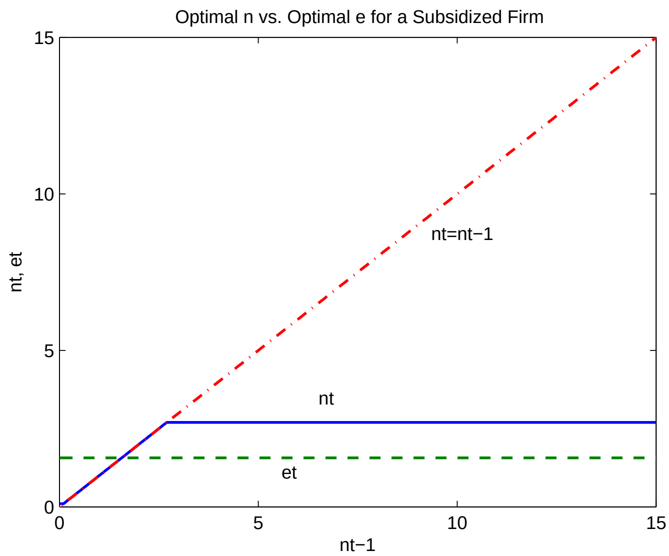


Note: Since e_t is constrained to be less than n_t, this represents the circumstance in which the subsidy take-up does not take place.

Figure 7 presents a situation in which e_t lays below n_t for some region of n_{t-1}. The optimal subsidy coverage in this case is the difference between n_t and e_t for $n_t < n_{t-1}$, which is presented by Figure 8. As we can see, the subsidy coverage increases with the state space n_{t-1} within the region of inaction, but stays constant above the region. The distance between the optimal n_t and e_t will increase as the current profitability shock either becomes more unfavorable relative to future prospects, or the current shock becomes highly transitory. The subsidy take-up state spaces are further investigated in the appendix, in which the optimal n_t and e_t are plotted against both n_{t-1} and ε_t.

Now, I will illustrate two cases contrasting differences in the behavior of eligible and non-eligible firms facing the same values for state variables. As mentioned previously, the purpose of this comparison is to study the marginal change in firm behavior that subsidy eligibility induces. For that reason, I restrict attention to the portion of the state space of the

Figure 7: Employment and Production Decision Rule for a Subsidized Firm



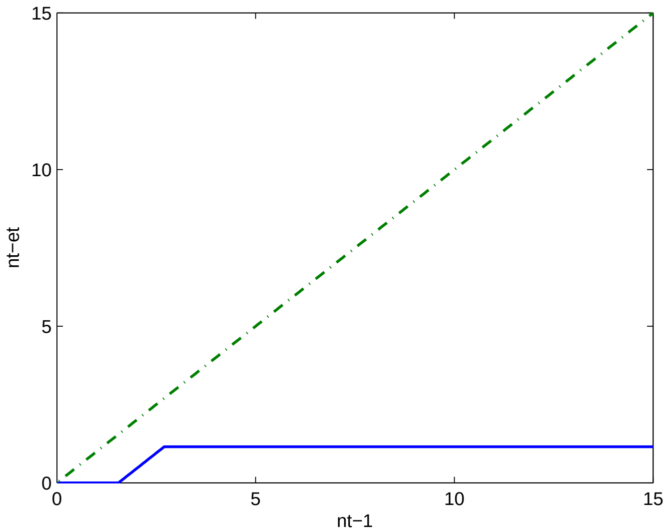
Note: Firms apply when the optimally chosen e_t is strictly below n_t.

profitability shocks and the level of employment such that subsidy take-up is optimal contingent on eligibility.[34] The behaviors of expanding firms are not discussed since they are unlikely to take up the subsidy. Nor will I discuss the situation where the firm is optimally in a region of inaction regarding employment. Furthermore, I will not focus on the reallocative implications of the subsidy program for the sake of simplicity, and therefore exit decisions are omitted from the analysis for now. Lastly, note that this exercise is not intended to compare behavior with the subsidy program to behavior without the subsidy program. That comparison will be performed using simulations from numerical dynamic programming in the next section.

The program requires that a firm not increase employment when receiving a subsidy,

[34] While subsidy take-up often takes place over the profitability and employment state space in which downsizing is a preferred option for the firms, this does not imply that all downsizing firms take up the subsidy. For example, firms are less likely to apply, the more persistent the sequence of profitability shocks becomes.

Figure 8: Optimal Subsidy Coverage for a Subsidized Firm



Note: This graph shows the distance between n_t and e_t in Figure 7 for n_t strictly greater than e_t.

but as previously mentioned, expanding firms are unlikely to take up subsidy at optimum.[35] As a result, subsidized firms have $n_{t-1} \geq n_t > e_t$. Ignoring the region of inaction, the first order conditions of equation 5 with respect to n_t and e_t for downsizing firms are:

$$(1-s)\gamma w = \beta EV_n(n_t, \varepsilon_{t+1}, \chi_{t+1}) + \tau_f \tag{6}$$

and

$$w - (1-s)\gamma w = f_e(e_t, \varepsilon_t), \tag{7}$$

where $EV_n(n_t, \varepsilon_{t+1}, \chi_{t+1})$ is the derivative of $EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$ with respect to n_t.[36]

[35]This result may not hold if labor adjustment costs are nonlinear in the number of workers, thereby creating a smoothing incentive for labor adjustment, or if adjustment costs are stochastic.

[36]Suppose we let λ_1 and λ_2 be the Lagrange multipliers of constraints $n_{t-1} \geq n_t$ and $n_t > e_t$, respectively. By complementary slackness, λ_2 must be zero for firms receiving the subsidy. Similarly, λ_1 must also be zero as we are considering downsizing firms.

Equation 6 shows that the unsubsidized portion of the labor cost of keeping an extra worker, given by the left side of the equation, must be equated with the marginal future benefit of keeping the worker as well as the benefit from avoiding the firing cost today. This provides the optimal condition for n_t. Similarly, equation (7) shows that the cost of utilizing a worker, given by the difference between the wage of a production worker and the cost a firm bears to sustain a worker unutilized, must be equated with the marginal revenue product. This characterizes the optimal condition for e_t.

Note that the concavity of EV implies that EV_n is declining in n_t.[37] Thus, holding everything else constant, optimal n_t will increase as s approaches one or as γ approaches zero. In addition, decreases in γ and increases in s or in the probability of being eligible π increase EV in the presence of labor adjustment costs. This result further increases the optimal n_t. On the other hand, the concavity of f implies that the optimal e_t will decrease with s and increase with γ. As a result, a higher s or lower γ, by reducing the costs of unutilized workers, increases the distance between the optimal n_t and e_t, thereby resulting in higher subsidy coverage.[38]

Equation (6) also implies that, holding EV constant, a higher firing cost τ_f increases n_t. Nonetheless, this effect is muted since an increase in τ_f indirectly reduces optimal n_t by reducing EV. Hiring costs do not affect n_t directly, as hiring costs already paid are sunk for non-expanding firms. But hiring costs reduce the optimal n_t indirectly by lowering EV. This

[37] Once exit decisions are included in the problem, EV is not always concave in n_t. EV is still concave over the range of n_t for which firms decide to stay in business.

[38] More formally, consider the case for a downsizing firm (i.e., $\lambda_1 = 0$). The implicit differentiation of equation (6) with respect to n_t and s gives $\partial n_t/\partial s = -[\gamma w + \beta(\partial EV_n/\partial s)]/\beta EV_{nn} > 0$ due to the concavity of EV and $\partial EV_n/\partial s > 0$, while the implicit differentiation of equation (7) with respect to e_t and s yields $\partial e_t/\partial s = \gamma w/f_{ee} < 0$ due to the concavity of f. Similarly, the implicit differentiation of equation (6) with respect to n_t and γ gives $\partial n_t/\partial\gamma = [(1-s)w - \beta(\partial EV_n/\partial\gamma)]/\beta EV_{nn} < 0$ due to the concavity of EV and $\partial EV_n/\partial\gamma < 0$, while the implicit differentiation of equation (7) with respect to e_t and γ yields $\partial e_t/\partial\gamma = -(1-s)w/f_{ee} > 0$ due to the concavity of f.

intuition is given by Hopenhayn and Rogerson (1993): while high firing costs may directly prevent firing, equilibrium employment can still be smaller if high labor adjustment costs substantially reduce profits.

Next, I will investigate the case in which the same downsizing firm is not eligible for the subsidy to examine the marginal change generated by eligibility. As mentioned previously, I still allow for the possibility of not utilizing some of their workers when firms are not eligible, but firms are not required to underutilize their workers. As a result, we have $n_{t-1} \geq n_t \geq e_t$. The first order conditions for this case is given simply by setting $s = 0$ for equations (6) and equation (7):

$$\gamma w = \beta EV_n(n_t, \varepsilon_{t+1}, \chi_{t+1}) + \tau_f \tag{8}$$

and

$$w - \gamma w = f_e(e_t, \varepsilon_t). \tag{9}$$

The intuitions here are similar to the previous ones.

Notice that the absence of s makes n_t to fall and e_t to rise. Where these two intersect, the constraint binds so that e_t does not exceed n_t.[39] More specifically, n_t given by equation (6) (hereafter denoted by n_t^s) is strictly higher than the n_t given by equation (8) (denoted simply by n_t) due to the concavity of EV. In addition, e_t given by equation (7) (hereafter denoted by e_t^s) is strictly smaller than the e_t given by equation (9) (denoted simply by e_t) due to the concavity of f. Consequently, for a given profitability shock ε_t, the following condition holds

[39]With the absence of s, we can see that the distance between n_t and e_t shrinks faster as γ gets closer to one. Therefore, higher γ reduces the likelihood of a firm idling some of its workers in the absence of a subsidy, provided that τ_f is low enough. Nevertheless, this is not to say that there is no labor hoarding without subsidy. The change in the intensity of the labor inputs' use is a common practice, but this feature is not modeled in this paper for a simpler exposition of the effects of the policy.

for a downsizing firm that applies for a subsidy when eligible[40]:

$$n_t^s > n_t \geq e_t > e_t^s. \tag{10}$$

That is, an eligible firm keeps the level of employment higher, and output lower, in comparison with a non-eligible firm.

Finally, combining equation (6) and equation (7) (or equation (8) and equation (9)), we obtain the following:

$$w - \tau_f = \beta E V_n(n_t, \varepsilon_{t+1}, \chi_{t+1}) + f_e(e_t, \varepsilon_t). \tag{11}$$

This result implies that when firms are downsizing, they set the expected marginal future benefit of an employed worker, combined with the marginal revenue product of a utilized worker, equal to the difference between the wage and firing cost. The firing cost is subtracted from wage as it represents the benefit from avoiding a payment that would otherwise be due to the marginal fired worker.[41]

Next, using the first order conditions given above, we can examine each of the components which affects subsidy take-up. Let $V^s(n_{t-1}, \varepsilon_t \mid \chi_t = 1)$ denote the value function satisfy-

[40]Keep in mind that the condition given by equation (10) characterizes the employment and production behavior of subsidized and unsubsidized firms under the same subsidy program with the same s and π. If we wish to compare the behavior of a firm under the regime without the subsidy program ($s = 0$, $\pi = 0$) and a firm under the regime with the subsidy program ($s > 0$, $\pi > 0$), we also need to take into account the effect of subsidy on EV. EV will be higher under the subsidy regime, so that the associated optimal n_t will rise even further compared to the optimal n_t under the regime without subsidy.

[41]On the other hand, the first order condition for an expanding firm is:

$$w + \tau_h = \beta E V_n(n_t, \varepsilon_{t+1}, \chi_{t+1}) + f_e(n_t, \varepsilon_{t+1}). \tag{12}$$

In this case, hiring costs show up as a cost of having an extra worker. Moreover, $n_t = e_t$ holds at an optimum for expanding firms.

ing first order conditions given by equations (6) and (7) (i.e., n_t^s and e_t^s) and $V(n_{t-1}, \varepsilon_t \mid \chi_t = 0)$ denote the value function with the first order conditions given by equations (8) and (9) (i.e., n_t and e_t.) Firms are better off with the subsidy when $V^s(n_{t-1}, \varepsilon_t | \chi_t = 1) > V(n_{t-1}, \varepsilon_t | \chi_t = 0)$. That is, the following condition must hold for a subsidy take-up to take place:

$$\underbrace{(n_t^s - e_t^s)s\gamma w}_{\text{total subsidy receipt}} + \underbrace{\tau_f(n_t^s - n_t)}_{\text{savings on firing costs}} + \underbrace{\{\beta[EV(n_t^s, \varepsilon_{t+1}, \chi_{t+1}) - EV(n_t, \varepsilon_{t+1}, \chi_{t+1})]\}}_{\text{change in future value}}$$
$$+ \underbrace{(1-\gamma)w(e_t - e_t^s)}_{\text{reduced wage payments}} > \underbrace{\{f(e_t, \varepsilon_t) - f(e_t^s, \varepsilon_t)\}}_{\text{reduction in revenue}} + \underbrace{\gamma w(n_t^s - n_t)}_{\text{increased employment costs}} . \tag{13}$$

The first term on the left represents the total subsidy received by the firm, the second term shows savings on firing costs with the subsidy, while the third term captures the change in the expected marginal future benefit arising from the different choices of n_t, and the fourth term represents the savings on labor costs arising from increasing the number of unutilized workers (i.e., firms pay γw instead of w so that the reduction in payment is $w - \gamma w$ or $(1-\gamma)w$ for each unutilized worker). In contrast, the first term on the right represents the reduction in revenue associated with reduced production and the second term represents the increase in the cost to the firm for sustaining excess workers through the subsidy program. Notice that with the subsidy, firms benefit from the reduced wage payments at the production worker margin, while firms lose from higher labor costs at the employment margin.

Obviously, the first and the second terms on the left and the last term on the right are positive when a firm applies for the subsidy, according to equation (10). Comparing "savings on firing costs" and "increased employment costs," the benefit of applying rises relative to the cost as the size of the firing cost, τ_f, increases relative to the cost of sustaining a worker, γw, and vice versa. Here, I call this a direct effect of τ_f. The relative sizes of τ_f and γw also indirectly affects the benefit of the subsidy through the third term on the left. Equation (6) and equation (8) show that if $(1-s)\gamma w > \tau_f$, then $EV_n > 0$ for both equations, and in particular, $EV(n_t^s, \varepsilon_{t+1}, \chi_{t+1}) > EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$. On the contrary, if $\gamma w < \tau_f$, then $EV_n < 0$ for both equations and $EV(n_t^s, \varepsilon_{t+1}, \chi_{t+1}) < EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$.[42] That is, when firing costs are very high, the optimal level of n_t is already so high that increasing n_t through the subsidy reduces the expected future value. In the later exercise, we will see that higher firing costs in general increase subsidy take-up even when $\gamma w < \tau_f$, suggesting that the direct effect dominates.[43]

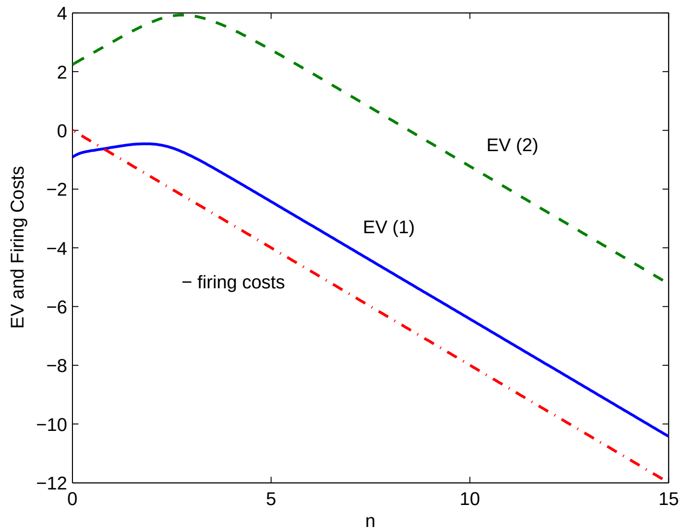
I now investigate the exit decisions of firms. Firms will decide to exit from the market when the expected loss of staying in the market is greater than the cost of firing its entire workforce (i.e., $EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$ is smaller than $-\phi(0, n_t)$). Since $EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$ considered here is concave and $-\phi(0, n_t)$ is linearly declining in n_t, the threshold level of the exit decision will be given by the intersection of $EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$ and $-\phi(0, n_t)$ when they are plotted against n_t while holding everything else constant. That is, the intersection gives the upper bound of n_t below which firms decide to exit for a given ε_t. EV and firing costs are plotted against n_t in Figure 9. Here, $EV(2)$ corresponds to a higher level of profitability shock compared to $EV(1)$. As the figure shows, no firms with a profitability shock corresponding to $EV(2)$ will exit from the market, while some small firms with a profitability shock corresponding to $EV(1)$ will exit. The subsidy shifts EV up slightly for all n_{t-1}, thereby reducing the upper bound of n_{t-1} for exiting. This result, combined with the higher employment induced by the subsidy program, reduces the equilibrium amount of exit at the steady-state.

The strategy used in order to solve the numerical dynamic optimization problem is

[42]Furthermore, the slope of EV given by equation (6) is negative and the slope given by equation (8) is positive if $\gamma w > \tau_f > (1-s)\gamma w$. In this case $EV(n_t^s, \varepsilon_{t+1}, \chi_{t+1}) - EV(n_t, \varepsilon_{t+1}, \chi_{t+1})$ can be either positive or negative.

[43]The size of hiring costs τ_h, on the other hand, only has an indirect effect through the third term on the left by affecting EV.

Figure 9: The Threshold Level of Exit Decision, EV vs. Firing Costs



Note: Firms decide to exit from the market when the expected loss of staying in the market is greater than the cost of firing its entire workforce. $EV(2)$ corresponds to a higher level of profitability shock compared to $EV(1)$.

provided in the appendix. Using the solutions to problem given by equation (5), we obtain a stationary distribution over the employment and profitability shock pairs for a given level of entry M. This stationary distribution, in turn, will provide us the rates of entry, exit, job reallocation, average employment, average output and average productivity in a stationary equilibrium. Furthermore, a mass of size M new entrants are added each period in obtaining a stationary distribution through contraction mapping. Following Hopenhayn and Rogerson (1993), the starting level of profitability shock (or put differently, initial luck of the draw) for an entrant is taken from the uniform distribution, and all entrants start at zero employment. The boundaries of this uniform distribution are set by the condition of the discretization of the AR(1) idiosyncratic profitability shock process explained in the following section.[44] After

[44]As explained in the next section, the upper bound and the lower bound are set at three standard deviations away from the mean, and the state space of idiosyncratic profitability shock is discretized into forty states. The use of an uniform distribution was preferred over that of a stationary or normal distribution, since these

the initial profitability shock, entrants evolve just as incumbents. Furthermore, entering firms are assumed not to receive a subsidy with their first production, and they must produce at least once before exiting from the market.

Denoting λ_t as a vector which describes the distribution over the entire set of employment levels and profitability shocks at period t, and $T(\lambda_t, M)$ as the transition matrix that maps the state at time t to the next state period given firms' decision rules, the state transition equation is given by $\lambda_{t+1} = T(\lambda_t, M)$. Accordingly, the time stationary distribution is described as a vector $\widehat{\lambda}$ such that $\widehat{\lambda} = T(\widehat{\lambda}, M)$. This distribution provides us with steady-state average employment in the economy. Moreover, the stationary distribution over production-profitability shock pair can be constructed from $\widehat{\lambda}$, by moving the corresponding fraction of subsidized firms to the optimally chosen level of production given by the first order condition of e, obtained from equation (7) for each level of shock. This distribution, in turn, provides us with the steady-state level of average production in the economy.

Because the growth rate of the industry is held constant in equilibrium, the number of firms that exit the market must be offset by the number of firms that enter the market M. Thus, the analysis is one in which there is no net entry, as exit and entry rates are identical in the steady-state. This simplification also follows Hopenhayn and Rogerson (1993). Since total employment is held constant in equilibrium, the number of jobs destroyed by incumbents and exiting firms have to be matched by the amount of jobs created by the incumbents and entering firms.

Finally, the operator T is homogeneous of degree one in $\widehat{\lambda}$ and M. Consequently, the

distributions would reduce the steady-state rate of exit (and hence entry) by reducing the number of firms that start off poorly.

rate of entry (and therefore the rate of exit) remains constant regardless of the size of M, as doubling M also doubles the total number of firms in a stationary equilibrium. Likewise, choosing a particular level of M corresponds to choosing a particular measure of firms and the total amount of employment in a stationary equilibrium, while statistics such as average employment, average output and productivity and the rates of job creation and destruction are unaffected by the choice of M. Even though a positive subsidy can potentially affect the total number of firms through M by raising the expected value of starting a business, M has not yet been endogenized in this model. In the following section, the equilibrium amount of entry M is simply set so that the total number of firms in equilibrium are the same for the subsidy case with $s > 0$ and the benchmark case with $s = 0$.

4 Results

4.1 Basic Setup and Calibration

To find an equilibrium via numerical dynamic programming, I begin by specifying the production function as:

$$f(e_t, \varepsilon_t) = \varepsilon_t \cdot e_t^{\theta} \text{ where } 0 < \theta < 1. \tag{14}$$

The path for the profitability shocks ε_t is given as follows:

$$\varepsilon_t = \alpha_t + u_t, \tag{15}$$

and

$$\alpha_t = \left\{ \begin{array}{c} \alpha_g \text{ with prob. } \delta \text{ if } \alpha_{t-1} = \alpha_g \\ \alpha_b \text{ with prob. } 1-\delta \text{ if } \alpha_{t-1} = \alpha_g \\ \alpha_g \text{ with prob. } 1-\delta \text{ if } \alpha_{t-1} = \alpha_b \\ \alpha_b \text{ with prob. } \delta \text{ if } \alpha_{t-1} = \alpha_b \end{array} \right\} \text{ where } \alpha_g > \alpha_b > 0 \tag{16}$$

and

$$u_t = \rho u_{t-1} + v_t \text{ where } 0 < \rho < 1 \text{ and } v_t \sim i.i.d. \text{ with } E[v_t] = 0. \tag{17}$$

Here, α_t represents the aggregate state. It follows a two-state Markov process with symmetric transition probability δ. Whereas actual business cycles arguably display asymmetric transition probabilities with the good state being longer than the bad state, a symmetric probability was used to reflect the longer than usual downturn experienced by the Japanese economy during the 1990s.[45] Meanwhile, u_t captures the idiosyncratic profitability shock, which follows an AR(1) process. The parameter ρ is the persistence of idiosyncratic shocks that firms receive each period, and v_t is a Gaussian white noise process with the standard deviation σ_v. For a given level of persistence ρ and the standard deviation σ_v, a corresponding forty-state Markov transition matrix and state vector for idiosyncratic shocks were created to approximate the AR(1) process for each level of α. Further, for each aggregate state, the upper and lower bounds of the shock are set at three standard deviations of u_t away from α_g and α_b. Note that forty idiosyncratic states combined with two aggregate states yields a total of eighty profitability states.

The profitability shocks can be interpreted as technology shocks or as demand shocks

[45] The asymmetric transition probability reduces the steady-state fraction of subsidized workers and makes it more difficult to match with the description of the data during the 1990s.

since ε_t will be multiplied by the price level p which is normalized to one. Here, I do not consider the distinction between supply and demand shocks, and simply regard ε_t as profitability shocks. Furthermore, note that the steady-state statistics in section (4.2), computed analytically by the stationary distributions, refer to the average figures of both aggregate states. Alternatively, the steady-state statistics for a good aggregate state and a bad state can be computed separately. Nonetheless, the average statistics were used in order to measure the long-run impact of the subsidy. The second moment properties of the subsidy in terms of the volatility of employment, productivity and output (i.e., fluctuation around the long-run mean) are examined via simulation in section (4.3), instead of using an analytical computation.

Table 2: Parameter Values used to obtain Stationary Distributions

$w = 1$	wage
$\tau_h = 0.8$	hiring costs
$\tau_f = 0.8$	firing costs
$c_f = 2$	fixed cost of operation
$r = 0.04$	interest rate
$\beta = (1/(1+r)) = 0.96$	discount rate
$\gamma = 0.8$	fraction of wage paid to unutilized workers
$\pi = 0.5$	prob. of being eligible for the subsidy
$s = 2/3$	subsidy coverage
$\theta = 0.55$	labor share of total cost
$\rho = 0.75$	persistence of idiosyncratic shocks
$\sigma_v = 0.5$	standard deviation of v_t
$\alpha_g = 3.13$	mean profitability of good state
$\alpha_b = 2.27$	mean profitability of bad state
$\delta = 0.6$	aggregate state transition probability

Key parameters used to solve the model are summarized in Table 2. Since subsidy data is only available annually, the time interval is set to one year. Moreover, the focus of the exercise will be the 1990s, during which the subsidy bill increased and data by two-digit sector is available. The wage is normalized to one, and both hiring and firing costs are set equal to

80% of the annual wage.[46] Later, we will examine the impact of higher adjustment costs by setting both hiring and firing costs equal to the annual wage. The fixed cost of operation (or entrepreneur's opportunity cost) is set to twice the wage. The annual interest rate is set equal to 4%. This figure corresponds to the government financial institutions' key lending rate to small- and medium- size enterprizes averaged in the 1990s.[47]

The EAS provides a guideline on the fraction of wages that firms should pay to subsidized workers, and it does not require that subsidized workers be paid the full amount. Accordingly, payment to unutilized workers is set equal to 80% of the wage. This number was estimated by combining three figures: the annual salary of manufacturing workers, taken from the *Basic Survey on Wage Structure*; the average work days of the manufacturing sector, provided by the *Monthly Labor Statistics*; and the average subsidy cost per worker per day as described in section (2.2).[48] The estimated subsidy cost per person per day is about 42% of the average basic wage between 1985 and 2001. This result implies that if $s = 1/2$, $\gamma = 0.94$ (or $\gamma = 0.84$ if instead of the basic wage, the actual wage which includes overtime is used) and if $s = 2/3$, $\gamma = 0.71$ (or $\gamma = 0.63$ if the actual wage is used).[49] The parameter value is set around the midpoint at $\gamma = 0.8$.

The probability of being eligible for the subsidy program each year is set equal to 50%. This seems reasonable given the high concentration of subsidies in the iron and steel industry

[46] Although the price is also normalized to one in the model, it is allowed to fluctuate relative to the wage as it is multiplied by a profitability shock.

[47] The interest rate data used in this paper is made available at the Bank of Japan's website in Japanese: http://www.boj.or.jp/stat/dlong_f.htm.

[48] Both the *Basic Survey on Wage Structure* and the *Monthly Labor Statistics* are published by the Ministry of Labor (current Ministry of Health, Labor and Welfare). The data used in the paper is posted on the website of the Japan Institute of Labor Policy and Training in Japanese: http://stat.jil.go.jp.

[49] Since the estimated subsidy cost per work day is not available by two-digit sectors, these estimates are for the entire manufacturing sector.

during the 1990s.[50] The subsidy coverage is set equal to 2/3 of the wage paid to unutilized workers. The parameter θ, which equals the labor's share of total cost, is set to 0.55; this figure corresponds to the average cost share of labor (excluding intermediate inputs) between 1973 and 1998 given by the JIP database.

The persistence of the shock is set equal to 0.75, and the standard deviation of v_t is set equal to 0.5.[51] The mean profitability shock in the bad state (α_b) is set at 2.27, so that the lowest shock in a bad state takes a positive value, and the distance between α_g and α_b is set slightly above one standard deviation of idiosyncratic shocks.[52] Here, α_g is set at 3.13. The probability that the aggregate state persists (δ) is equal to 0.6. These parameter values are assigned to generate realistic statistical properties of key variables such as the fraction of subsidized workers, job creation and destruction rates, and entry and exit rates. Employment was discretized in 301 grid points ranging from zero to fifteen; the upper bound was set to guarantee that it exceeds equilibrium employment with the highest value of the profitability shock.

Average productivity is defined as total output divided by total employment. More specifically, let N and S denote the number of employment grid points and the total number of profitability states, respectively. Now, using $\widehat{\lambda}(n_i, \varepsilon_j)$ and $\widehat{\lambda}(e_i, \varepsilon_j)$ to represent the proportion of firms over each (n_i, ε_j) and (e_i, ε_j) pairs in a stationary equilibrium, the average productivity

[50]Unfortunately, information on the fraction of firms covered by the subsidy is not currently available.

[51]These two combined implies that the standard deviation of the idiosyncratic shock is about 0.756 since $\sigma_u = \sqrt{\sigma_v^2/(1-\rho^2)}$.

[52]This specification implies that idiosyncratic shocks play a larger role in controlling firm's fortune than aggregate shocks do. Also, note that the lowest value of ε_t is 0.002 when we set $\alpha_b = 2.27$.

is defined as:

$$\begin{aligned}\text{Average productivity} &= \frac{\text{Total Output}}{\text{Total Employment}} \\ &= \sum_{i=1}^{N}\sum_{j=1}^{S}\left(\frac{e_i \cdot \widehat{\lambda}(e_i,\varepsilon_j)}{\sum_{i=1}^{N}\sum_{j=1}^{S} n_i \cdot \widehat{\lambda}(n_i,\varepsilon_j)}\right)\left(\frac{f(e_i,\varepsilon_j)}{e_i}\right). \qquad (18)\end{aligned}$$

The term in the first bracket shows the relative share of utilized workers in each $(e_{i,}\varepsilon_j)$ pair of the stationary distribution, and the second term reflects output per utilized worker. Notice that this definition includes subsidized workers, who produce zero output, in calculating the productivity.

I also present a productivity measure adjusted for hiring and firing costs and the subsidy cost per worker. This measure controls for the gain associated with having to spend less resources in hiring and firing with the subsidy, as well as the associated loss in the form of a higher government deficit and/or higher tax. The calculation is done simply by subtracting the hiring and firing costs per worker as well as the cost of the subsidy per worker from average productivity as defined by equation (18). Yet, this should not be interpreted as a welfare measure, as I have not modeled the utility benefit of the subsidy for workers nor the gains associated with sustaining better job-worker matches for experienced workers.

Average productivity is alternatively defined as total output divided by the total number of utilized workers:

$$\begin{aligned}\underset{\text{(based on utilized workers)}}{\text{Average productivity}} &= \frac{\text{Total Output}}{\text{Total Number of Utilized Workers}} \\ &= \sum_{i=1}^{N}\sum_{j=1}^{S}\left(\frac{e_i \cdot \widehat{\lambda}(e_i,\varepsilon_j)}{\sum_{i=1}^{N}\sum_{j=1}^{S} e_i \cdot \widehat{\lambda}(e_i,\varepsilon_j)}\right)\left(\frac{f(e_i,\varepsilon_j)}{e_i}\right). \qquad (19)\end{aligned}$$

Obviously, this definition excludes unutilized workers. Hence, comparing equation (18) and equation (19) for the same level of subsidy coverage s captures the direct effect of hoarding on average productivity. More specifically, the ratio of productivity based on employment to productivity based on utilized workers (both when $s = 2/3$) shows a reduction in productivity as a direct result of labor hoarding (i.e., the ratio of productivity calculated using equation (18) to that given by equation (19)). Since this figure is equivalent to the ratio of the total number of utilized workers to total employment, one minus this ratio matches the fraction of subsidized workers.

Finally, the steady-state rate of job turnover is the ratio of the total number of jobs destroyed by incumbents and exiting firms to total employment at the steady-state. Since total employment stays constant in a stationary equilibrium, this figure obviously equals the steady-state rate of job creation, which is the ratio of the jobs created by both incumbents and entrants to total employment at the steady-state. These measures allow us to evaluate the magnitude of total job reallocation occurring in the economy.

4.2 Stationary Distribution

This section examines the properties of stationary distribution. In order to examine the effects of subsidies on productivity, the benchmark model sets $s = 0$ while the subsidy case sets $s = 2/3$. First, I investigate a case without volatility in aggregate shocks. The value of α in this exercise is set equal to 2.7. Then I will add volatility in α, while preserving the mean, as specified in the previous section. Finally, I will increase the hiring and firing costs from 80% of the wage to 100% to investigate the impact of this change. As mentioned previously, the profitability shocks are parameterized to generate realistic values for the fraction of subsidized workers, the rates of entry and exit, and the rates of job creation and destruction.

Despite the fact that studies on annual rates of entry, exit, job creation, and destruction in Japan are not extensive, due to a lack of data comparable to the LRD for American manufacturing establishments, Motonishi and Tachibanaki (1999) attempt to estimate these figures by using the establishment level data for 1988, 1990 and 1993 from *Census of Manufacturers* compiled by the Japanese Ministry of Economy, Trade and Industry. The rate of entry (exit) on an annualized basis is 8.74% (7.91%) for the iron and steel industry for 1988−1990, and 5.68% (8.15%) for 1990−1993.[53] Motonishi and Tachibanaki also provide the rate of job creation and destruction (adjusted on an annualized basis) during these periods.[54] The rate of job creation (destruction) on an annualized basis provided by this study is 4.55% (4.81%) for the iron and steel industry for 1988−1990, and 2.91% (4.83%) for 1990−1993.

In this exercise, the number of entrants M is set so that the total number of firms is equal to one in both cases. As mentioned before, increasing M increases the total number of firms, and hence total employment and output proportionally, but average size as well as average firm output remains the same. Here, I assume that the impact of the subsidy on M is trivial. Moreover, the values for the average size of firms (or total employment), average output by firm (or total output) and average productivity obtained for the subsidy case are normalized

[53] While this data includes all manufacturing establishments with more than 4 employees, it does not include firms that have entered and exited between census years. As a result, the figures on entry and exit rates presented in this study (which are adjusted on an annualized basis) may underestimate the true magnitude of entry and exit.

[54] Again, the annual rates of job flows may be underestimated since firms that enter and exit between the census years are not included. Furthermore, employment volatility during the census years could potentially generate smaller figures for both job creation and destruction rates when calculated on an annualized basis than the actual annual job creation and destruction rates (i.e., if a firm hires 100 new employees in 1990 and fires 100 in 1993, this firm's employment stays constant over the 1990 and 1993 census). GDP growth rates fluctuate slightly between 1988−1990, but follow a steady decline for 1990−1993, so that the underestimation arising from employment volatility is potentially less for the latter interval.

by the corresponding benchmark values to facilitate comparison, and for this reason these benchmark values are set equal to one.

Table 3: Summary Statistics of Stationary Distributions without Aggregate Volatility

$\alpha = 2.7$	s = 0	s = 2/3
Fraction of workers covered by the subsidy	0.0000	0.0036
Exit rate	0.0496	0.0486
Job turnover rate	0.0383	0.0378
Total number of firms	1.0000	1.0000
Average firm level employment	1.0000	1.0014
Average firm level output	1.0000	0.9985
Average productivity based on employment	1.0000	0.9971
— adjusted for hiring and firing costs	1.0000	0.9974
— adjusted for hiring, firing and subsidy costs	1.0000	0.9961
Average productivity based on utilized workers	1.0000	1.0007

The key statistics given by the stationary distributions without aggregate volatility are summarized in Table 3. Overall the changes are small. The fraction of subsidized workers generated by the stationary distribution is 0.36%. The exit rate drops from 4.96% to 4.86% with the subsidy, while the job turnover rate falls from 3.83% to 3.78%. Average firm size is 0.14% higher and average firm level output is 0.15% lower. The reduction in output in spite of higher employment is caused by the presence of unutilized workers.

Average productivity falls by about 0.29% with the subsidy program. When average productivity is calculated based on utilized workers, it increases slightly by 0.07%. This gain is generated by the increased flexibility of production decisions via the subsidy program: under the benchmark case without subsidy, firms hold some excess workers who are used for production due to the presence of labor adjustment costs. Whereas firms hold even more excess workers with the subsidy program, these workers are not used for production, thereby increasing productivity when calculated only in terms of utilized workers.

Here, the drop in productivity due to labor hoarding, which corresponds to the size of subsidized workers, is 0.36%. In addition, when average productivity is adjusted for labor adjustment costs, the negative impact of the subsidy on productivity shrinks, reflecting the fact that the subsidy helps firms avoid labor adjustment costs. In spite of this gain, when we further control for the cost of the subsidy, average productivity falls slightly further in comparison with the benchmark value, indicating that the cost of the subsidy is higher than savings on labor adjustment costs.

Now we add aggregate volatility without changing the mean α, while keeping hiring and firing costs at 0.8. The results are presented in Table 4. The fraction of subsidized workers generated by the stationary distribution now increases to 1.28%. As expected, this result implies that volatility increases subsidy take-up. Since the estimated annual average fraction of subsidized workers in the iron and steel industry is 2.1%, the model does not exaggerate the extent of subsidy coverage. The model's exit rate is 4.89% when the subsidy is set equal to zero, and it drops to 4.73% when the subsidy is set equal to two-thirds of payments to unutilized workers. The job turnover rate falls from 4.05% to 3.91% when the subsidy program is in place. Compared with the "no aggregate volatility" case, the drop in both the exit rate and the job turnover rate is slightly bigger with volatility. This result may be due to the fact that the subsidy's benefit increases with higher aggregate volatility, thereby raising EV.

Similar to the "no aggregate volatility" case, average firm level employment goes up with the subsidy while average firm level output drops. Again, higher average employment does not lead to higher average output at the firm level, due to the presence of subsidized

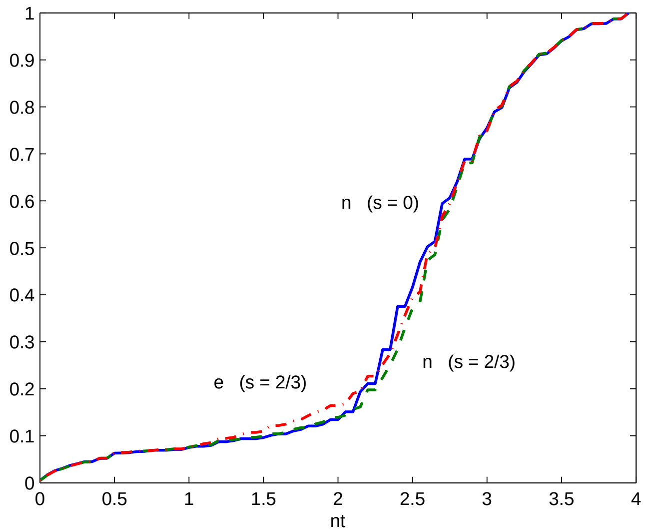
Table 4: Summary Statistics of Stationary Distributions with Aggregate Volatility

$\alpha_g = 3.13$, $\alpha_b = 2.27$	Low adj. costs $\tau_h = 1 = \tau_f = 0.8$		High adj. costs $\tau_h = 1 = \tau_f = 1$	
	$s = 0$	$s = 2/3$	$s = 0$	$s = 2/3$
Fraction of workers covered by the subsidy	0.0000	0.0128	0.0000	0.0157
Exit rate	0.0489	0.0473	0.0508	0.0484
Job turnover rate	0.0405	0.0391	0.0369	0.0343
Total number of firms	1.0000	1.0000	1.0000	1.0000
Average firm level employment	1.0000	1.0096	1.0000	1.0187
Average firm level output	1.0000	0.9982	1.0000	1.0015
Average productivity based on employment	1.0000	0.9887	1.0000	0.9831
— adjusted for hiring and firing costs	1.0000	0.9895	1.0000	0.9851
— adjusted for hiring, firing and subsidy costs	1.0000	0.9850	1.0000	0.9796
Average productivity based on utilized workers	1.0000	1.0016	1.0000	0.9988

workers. Average productivity based on employment, given by equation (18), falls about 1.13% with the subsidy. As before, average productivity based on utilized workers goes up by 0.16% due to the flexibility of production decisions with the subsidy. The sum of these two measures approximately corresponds to the drop in productivity as a direct result of labor hoarding. As before, average productivity falls even further after controlling for labor adjustment and subsidy costs.

The drop in productivity due to labor hoarding generated by this model is quite successful in approximating the impact of labor hoarding in the data as described in section (2.2). Namely, the adjusted TFP (i.e., average productivity based on utilized workers) is higher than unadjusted TFP (average productivity based on employment) by about 1.2% in the data between 1990 and 2001. Nonetheless, in the growth accounting exercise, the drop in TFP is smaller than the fraction of subsidized workers, as only the labor share of total cost applies to

Figure 10: Cumulative Distribution Functions of Three Stationary Distributions



Note: The solid line shows the cdf of firm level employment when the subsidy is set equal to zero. The dashed line shows the cdf of employment when the subsidy is set equal to 2/3 of wage. The dotted line shows the stationary distribution in terms of utilized workers when subsidy is set equal to 2/3 of wage.

the overall reduction in productivity.[55]

Figure 10 provides cumulative distribution functions of three stationary distributions: a stationary distribution over employment for all levels of idiosyncratic and aggregate shocks when $s = 0$; a stationary distribution over employment for all levels of idiosyncratic and aggregate shocks when $s = 2/3$; and finally a stationary distribution over utilized workers for all levels of idiosyncratic and aggregate shocks when $s = 2/3$. Note that the distributions are bumpy since the state spaces (employment and profitability) are discontinuous. The figure confirms that the average firm level employment is higher when the subsidy program is in place, while we cannot tell whether or not the average firm level production is larger with the

[55] Although the iron and steel sector has gone through a process of substitution from labor towards capital over the last couple of decades, the intensity of capital usage and labor are likely to be complementary over a much shorter horizon (i.e., a year or less). The short-run complementarity assures that the correlation between capital usage and labor is high at the high frequency, and hence introducing capital into the model should not undermine the main results.

subsidy program.[56]

The final case investigates the impact of higher adjustment costs. Here, hiring and firing costs are set equivalent to the annual wage. The results are also provided by Table 4. The fraction of subsidized workers rises further to 1.57%. The rate of reallocation in terms of exit and job turnover falls again with the subsidy: the exit rate drops from 5.08% to 4.84%, while the job turnover rate falls from 3.69% to 3.43%. A comparison with the "low adjustment costs" case reveals that the exit rate rises while the job turnover rate drops with the increase in adjustment costs. Note that high labor adjustment costs have two competing effects on exit behavior: while high firing costs increase the cost of exiting and therefore prevent exit, high labor adjustment costs (both hiring and firing) reduce the expected value and encourage exit. In our example, the exit rate rises with higher adjustment costs, indicating that the "encouragement" effect of high firing costs outweighs the "prevention" effect of high firing costs. Nonetheless, higher adjustment costs still seem to reduce the job turnover rate. Furthermore, the impact on the average size of firms is greater with higher adjustment costs, as average employment rises by 1.87% compared to the benchmark.

Average productivity based on employment falls by 1.7%, while unlike the first two cases, average productivity based on utilized workers falls by 0.12%. The drop in the second productivity measure implies that the distortion that the subsidy generates in the reallocation measures is greater with the "higher adjustment costs," and this offsets the productivity gain generated by the flexible production adjustment provided by the subsidy. When productivity is adjusted for hiring/firing costs, the drop in productivity is not as severe, as a result of the

[56] The ambiguity is observed since the cdf for $e(s = 2/3)$ and the cdf for $n(s = 0)$ intersect (around the employment level equals to 2.3).

gains accrued from smaller adjustment costs. Despite this gain, productivity falls again below the baseline employment productivity, by 2.04%, when it is adjusted for both labor adjustment and subsidy costs.

Even though the direct effect of the subsidy on productivity observed in this section are small in all three cases, the indirect effect of the subsidy over the business cycle can be substantially larger. I will examine these results in the next section.

4.3 Simulation Results

In the previous section, we saw that the direct effect of the subsidy on steady-state productivity is more or less proportional to the number of subsidized workers. However, the simulation exercises reveal that even when the productivity effect is small, the effects of the subsidy on output and employment dynamics over business cycles are quite striking. Accordingly, in this section, cyclical implications of the subsidy program are highlighted via simulation.

For each simulation, a sequence of profitability shocks is generated for 150 periods from the Markov-process described above for 5000 firms. The idiosyncratic component of the profitability shock varies across firms, while the aggregate component is shared by all firms. Furthermore, using the steady-state condition, I replace an exiting firm with an entering firm so that the total number of firms remains constant.[57] When a new firm enters, a new sequence of the idiosyncratic component of profitability shocks is drawn from the distribution, and the

[57] Though exits would likely exceed entries during downturns, this simulation abstracts from the variations in net entries over the business cycle. As long as the effect of the subsidy program on the variations in net entries is small, normalization with the benchmark case insures that this simplification does not pose a significant problem in assessing the policy impact. If the subsidy reduces the variation in net entries, both employment and output should be less volatile than suggested by the results here. In this case, the employment volatility results will be enhanced, while the output volatility results will be mitigated.

firm starts with zero employment.

Table 5: Summary Statistics given by Simulation Exercises with Low Adjustment Costs

$\tau_h = 0.8$, $\tau_f = 0.8$	$s = 0$	$s = 2/3$	Ratio
Correlations between			
— total output and average productivity (n)	0.9870	0.9895	1.0025
	(0.0007)	(0.0006)	
— total output and average productivity (e)		0.9891	
		(0.0006)	
Standard deviations of			
— total output	0.1670	0.1717	1.0284
	(0.0006)	(0.0006)	
— total employment	0.0424	0.0399	0.9409
	(0.0007)	(0.0007)	
— average productivity	0.1320	0.1387	1.0512
	(0.0003)	(0.0003)	
— job creation rate	0.0205	0.0198	0.9680
	(0.0003)	(0.0002)	
— job destruction rate	0.0200	0.0186	0.9304
	(0.0002)	(0.0002)	

In addition to profitability shocks, a sequence of eligibility is also generated for all firms based on the unconditional probability π. After generating employment, output, entry and exit behavior for 5000 firms for 150 periods, the first 50 periods are deleted in order to eliminate the effects of the initial distribution. This entire exercise, in turn, was repeated 100 times to obtain the mean and the standard deviation of each statistic. Note that given the procedure described above, 'total output' and 'total employment' in this exercise refer to the total sample of 5000 firms.

First, I examine the "low adjustment costs" case that sets both hiring and firing costs to 80% of the annual wage. Then, I investigate the "high adjustment costs" case where both hiring and firing costs are increased to 100% of the annual wage to investigate its impact. Table 5 reports statistics obtained from simulating the "low adjustment costs" case. It provides statistics for $s = 0$ and $s = 2/3$, as well as their ratio, with the benchmark figure set as a denominator. Standard deviations of each statistics are reported in parentheses. Note that output, employment and productivity are now measured in natural logarithms. As the 'ratio' column shows, the correlation between total output and average productivity rises by 0.25% with the subsidy indicating that the procyclicality of productivity is stronger with the subsidy program. However, the predicted increase is very small.

The JIP database presented in section (2.2) showed that the correlation between TFP and real gross output falls from 0.7916 to 0.7843 when the subsidy adjustment is made, and the correlation between TFP and real value added falls from 0.9921 to 0.9906. In this theoretical exercise, the correlation between total output and average productivity falls slightly, from 0.9895 to 0.9891, when subsidized workers are taken into account in calculating average productivity (i.e., when I use equation (19) instead of (18)).

Perhaps the most significant finding of this exercise is that the standard deviation of output increases on average by 2.84% when $s = 2/3$ compared to when $s = 0$. This is a substantial increase in volatility given that the fraction of subsidized workers is only 1.3% of total employment at the steady-state. Intuitively, this results from a symmetric increase in output sensitivity to aggregate shocks: when the bad aggregate shock hits the economy, total output is lower than otherwise as the subsidy allows for a reduction in output while sustaining employment. When the good aggregate shock hits the economy, total output is higher with the subsidy program as firms spend less on hiring. Since the subsidy program keeps average employment higher, firms can more readily raise production in times of favorable shocks. The higher responses of output to both good and bad shocks generate more volatility over the business cycle.

Table 6: Summary Statistics given by Simulation Exercises with High Adjustment Costs

$\tau_h = 1$, $\tau_f = 1$	$s = 0$	$s = 2/3$	Ratio
Correlations between			
— total output and average productivity (n)	0.9896	0.9927	1.0032
	(0.0007)	(0.0007)	
— total output and average productivity (e)		0.9921	
		(0.0007)	
Standard deviations of			
— total output	0.1630	0.1687	1.0348
	(0.0007)	(0.0007)	
— total employment	0.0373	0.0327	0.8759
	(0.0008)	(0.0009)	
— average productivity	0.1322	0.1418	1.0722
	(0.0003)	(0.0004)	
— job creation rate	0.0177	0.0159	0.9008
	(0.0002)	(0.0003)	
— job destruction rate	0.0182	0.0149	0.8225
	(0.0002)	(0.0002)	

On the contrary, the volatility of employment falls by about 6% with the subsidy program in place. This reduced volatility matches the objective of the government to reduce undesired fluctuation in employment due to business cycles. The reduction comes from reduced job destruction during unfavorable aggregate conditions as well as stunted job creation during favorable times. The standard deviation of job creation falls by about 3.2% with the subsidy, whereas the standard deviation of job destruction falls by about 7%. Finally, the standard deviation of average productivity rises by 5.12%.[58]

Table 6 highlights the results of the "high adjustment costs" case. The fraction of

[58] Since labor productivity is now expressed in logs (i.e., $\ln(Y/N)$), the following formula applies:

$$var(\ln(Y/N)) = var(\ln Y) + var(\ln N) - 2cov(\ln Y, \ln N). \tag{20}$$

Note that since the variance of output is much larger than the variance of employment, the increase in the variance of output results in the higher variance of productivity, even with the reduction in the variance of employment. Furthermore, the covariance between output and employment falls with the subsidy as expected, thereby further increasing the variance of productivity under the subsidy case relative to the benchmark case.

subsidized workers given by the stationary distribution in this case is 1.59%. The results for correlations are similar to the "low adjustment costs" case except that the correlations are slightly higher due to higher adjustment costs. The volatility of output increases by about 3.5%, but the volatility of employment falls substantially by about 12%. This result is generated by a reduction in the volatility of job creation by 10% and job destruction by 18%. In addition, the standard deviation of average productivity rises by 7.2%.

The comparison between the "high adjustment costs" and "low adjustment costs" cases reveals that even when the effect of the subsidy on the steady-state employment and job reallocation rate is trivial, the effect on the volatility of employment over the business cycle is substantial. This result is mainly driven by the reduced sensitivity of job creation and destruction to aggregate shocks. For this reason, the policy leads to a substantial reduction in the volatility of job churning over the business cycles. Finally, although it is not reported in this paper, the volatility of output increases by 4.2% and the volatility of employment falls by 10% when the size of adjustment costs are further increased to $\tau_h = \tau_f = 1.5$, for the fraction of subsidized workers equal to 2%.[59]

5 Conclusion

This paper has examined the effects of the EAS, Japan's major employment insurance program, on average productivity, employment, and the volatility of output and employment over the business cycle, through the examination of the iron and steel industry. The partial equilibrium model described in this paper shows that the subsidy reduces average productivity

[59]Note that the effectiveness of the subsidy in reducing employment volatility is not linear in the size of adjustment costs because high adjustment costs are already associated with low employment volatility.

primarily by increasing the number of unutilized workers. Nevertheless, the direct impact of the subsidy on productivity is predicted to be small due to a small fraction of subsidized workers. On the contrary, simulation exercises reveal that the subsidy may have a substantial impact on the volatility of output and employment. In particular, when hiring and firing costs are set equal to 80% of the annual wage, the subsidy increases output volatility by 2.8% and reduces employment volatility by 6% over the business cycles, even when the fraction of subsidized workers is about 1.3%. When hiring and firing costs are increased equivalent to the annual wage, the volatility of employment drops by 12% while that of output increases by 3.5%.

While measures such as productivity, employment and output volatility are often used to evaluate welfare, I do not intend to draw a normative conclusion on the welfare effect of the subsidy program. Nevertheless, I believe that the implications highlighted in this theoretical exercise are important ones, providing policymakers a better understanding of the program, thereby allowing them to more successfully target their policy objectives. Here, I raise a couple of issues for a more complete welfare assessment. First, the paper predicts that the subsidy increases output volatility while reducing employment volatility. Consequently, an assessment of the policy requires an analysis of the cost of output volatility and the benefits of employment stability.[60] Second, while some labor market imperfections are assumed for subsidy take-up to take place (i.e., firing restrictions and rigid wage), I have not investigated how the subsidy program may enhance or reduce labor market imperfections.[61] Neither have I conducted a hypothetical comparison with a benchmark without labor market imperfections.

[60] For example, the subsidy program could bring a substantial benefit by promoting long-term employment if the skill/productivity of workers increases with tenure.

[61] For example, the subsidy could potentially enhance the downward rigidity of wage. Similarly, it may create less incentive to legislate reductions to firing restrictions and promote labor mobility.

The analysis presented here raises several additional issues for further investigation. First, since the quantitative impact of the subsidy on the volatility of output and employment is sensitive to the magnitude of labor adjustment costs, it will be important to quantify these costs accurately to evaluate the potential impact of the subsidy program. Second, the analysis treated the iron and steel industry as an independent economy with no interaction with other industries. New policy implications may arise if inter-industry interactions between high productivity sectors and low productivity sectors are present in the model.[62] Third, it seems worthwhile to investigate why the subsidy was so heavily concentrated in the iron and steel sector. Finally, employment volatility during the severe recession of the 1990s was surprisingly mild in Japan compared to other industrial nations, despite the fact that EAS coverage was highly concentrated in certain sectors of the economy.[63] It would be interesting to empirically investigate what factors contributed to the stabilization of employment.

[62] The subsidy program may have an inter-industry reallocation effect as some industries are more heavily subsidized than others. This feature could potentially add another dimension to the analysis of overall productivity dynamics.

[63] According to *Labor Force Survey*, the unemployment rate during the 1990s followed a steady increase rather than being cyclical. The highest unemployment rate at the trough from 1998-1999 was still below 5%.

Appendix

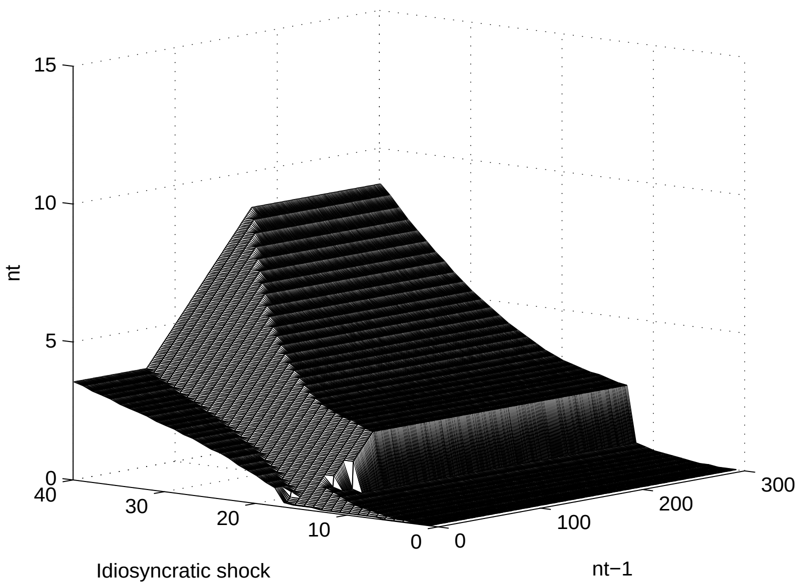
A. Graphic Illustration of Subsidy Take-up State Spaces

In this section, I graphically illustrate the state spaces over profitability shock and previous employment, in which firms decide to take up the subsidy. Figure 11 plots the unconstrained optimal choice of employment against previous level of employment and current profitability shock. Note that the optimal n_t here takes into account firms' exit decisions. Holding the previous level of employment constant, we see that the optimally chosen level of employment, n_t, increases as the level of idiosyncratic shock, ε_t, becomes higher. Also, notice that the optimal n_t jumps at the threshold level of shock below which firms decide to exit. Furthermore, holding the level of current profitability shock constant, the optimal n_t has a region of inaction in which employment stays constant, as explained in the main text.

Figure 12 plots the unconstrained optimal choice of utilized workers. Note that the unconstrained optimal e_t is affected neither by labor adjustment costs nor the expected future value. Accordingly, the decision rules are independent of the previous level of employment, and the figure exhibits a smooth curve.

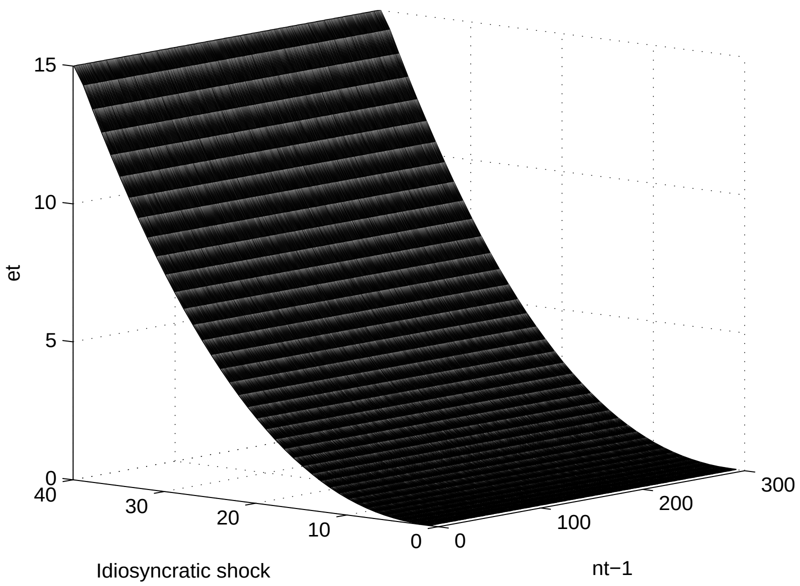
The optimally chosen n_t must exceed the unconstrained optimal e_t for firms to take advantage of the subsidy program. By comparing these two figures, we see that at a high level of idiosyncratic shocks, the optimal e_t exceeds the optimal n_t, and therefore, firms do not take-up the subsidy. However, as the level of idiosyncratic shocks becomes lower (i.e. around 20 in this case), n_t starts to exceed e_t and firms take up the subsidy. Furthermore, at even lower level of shocks (i.e. less than 13 in this case), firms do not take-up the subsidy as they exit from the market. Finally, expanding firms, whose optimal choices of n_t are observed at

Figure 11: The Unconstrained Optimal Level of Employment



Note: It plots the optimal choice of employment against the previous level of employment, n_{t-1}, and current profitability shock, ε_t.

Figure 12: The Unconstrained Optimal Level of Utilized Workers



Note: It plots the optimal choice of utilized workers against the previous level of employment, n_{t-1}, and current profitability shock, ε_t.

the bottom of the region of inaction for each idiosyncratic shock, do not take advantage of the subsidy program.

B. Strategy for Solving the Numerical Dynamic Optimization Problem

In this section, I explain the strategy used to solve the numerical dynamic optimization problem given by equation (5). The first method is to use a brute force and solve the problem using two choice variables, n_t and e_t. This method is straightforward, but computationally more time-consuming as it involves all combinations of n_t and e_t. The computational burden is doubled when we include limited eligibility since some firms now face a different profit maximization problem when $\chi = 1$.

The second method is to use the first order condition for e_t given by equation (7) and reduce the problem for the subsidy application case into one which involves only one choice variable, n_t. Note that this n_t does not take into account the current production decision, and therefore it is not an appropriate one when firms decide not to use the subsidy. To overcome this problem, two hypothetical value functions, $V^s(n_{t-1}, \varepsilon_t \mid \chi_t = 1)$ and $V(n_{t-1}, \varepsilon_t \mid \chi_t = 0)$ as described in the text, are created. By comparing these two, we can generate firm's decision rules regarding the subsidy take-up, $Z(n_{t-1}, \varepsilon_t, \chi_t)$, where $Z = 1$ corresponds to taking up a subsidy and $Z = 0$ corresponds to not taking up. When firms are not eligible, they follow $V(n_{t-1}, \varepsilon_t \mid \chi_t = 0)$ regardless of their subsidy decisions. This second method was used since it is computationally less time-consuming.

We also obtain the following decision rules: $X(n_{t-1}, \varepsilon_t, \chi_t)$, where $X = 1$ corresponds to exiting from the market and $X = 0$ corresponds to staying; $N(n_{t-1}, \varepsilon_t, \chi_t)$ and $E(n_{t-1}, \varepsilon_t, \chi_t)$, which give the optimal choices of employment and utilized workers, respectively, at time t. Furthermore, whenever $Z = 1$, a fraction π of firms follow the decision rules which correspond to $V^s(n_{t-1}, \varepsilon_t \mid \chi_t = 1)$ while the remaining fraction $1 - \pi$ of firms follow the decision rules implied by $V(n_{t-1}, \varepsilon_t \mid \chi_t = 0)$. On the other hand, when $Z = 0$, all firms follow the decision rules obtained from $V(n_{t-1}, \varepsilon_t \mid \chi_t = 0)$.[64]

[64]Strictly speaking, $\chi_t = 1$ for the fraction π of firms, but since they do not take-up the subsidy, their decision rules are the same as the case for $\chi_t = 0$.

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