ZOMBIE LENDING AND DEPRESSED RESTRUCTURING IN JAPAN

Ricardo J. Caballero
Takeo Hoshi
Anil K. Kashyap

ABSTRACT

In this paper, we propose a bank-based explanation for the decade-long Japanese slowdown following the asset price collapse in the early 1990s. We start with the well-known observation that most large Japanese banks were only able to comply with capital standards because regulators were lax in their inspections. To facilitate this forbearance the banks often engaged in sham loan restructurings that kept credit flowing to otherwise insolvent borrowers (that we call zombies). Thus, the normal competitive outcome whereby the zombies would shed workers and lose market share was thwarted. Our model highlights the restructuring implications of the zombie problem. The counterpart of the congestion created by the zombies is a reduction of the profits for healthy firms, which discourages their entry and investment. In this context, even solvent banks do not find good lending opportunities. We confirm our story's key predictions that zombie-dominated industries exhibit more depressed job creation and destruction, and lower productivity. We present firm-level regressions showing that the increase in zombies depressed the investment and employment growth of non-zombies and widened the productivity gap between zombies and non-zombies.

Ricardo J. Caballero
MIT
Department of Economics
Room E52-252a
Cambridge, MA 02142-1347
and NBER
caball@mit.edu

Anil K. Kashyap
Graduate School of Business
The University of Chicago
5807 S. Woodlawn Avenue
Chicago, IL 60637
and NBER
anil.kashyap@gsb.uchicago.edu

Takeo Hoshi
Graduate School of International Relations
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0519
and NBER
thoshi@ucsd.edu

1. Introduction

This paper explores the role that misdirected bank lending played in prolonging the Japanese macroeconomic stagnation that began in the early 1990s. The investigation focuses on the widespread practice of Japanese banks of continuing to lend to otherwise insolvent firms. We document the prevalence of this forbearance lending and show its distorting effects on healthy firms that were competing with the impaired firms.

Hoshi (2000) was the first paper to call attention to this phenomenon and its ramifications have been partially explored by a number of observers of the Japanese economy. There is agreement that the trigger was the large stock and land price declines that began in early 1990s: stock prices lost roughly 60% of their value from the 1989 peak within three years, while commercial land prices fell by roughly 50% after their 1992 peak over the next ten years. These shocks impaired collateral values sufficiently that any banking system would have had tremendous problems adjusting. But in Japan the political and regulatory response was to deny the existence of any problems and delay any serious reforms or restructuring of the banks.[1] Aside from a couple of crisis periods when regulators were forced to recognize a few insolvencies and temporarily nationalize the offending banks, the banks were surprisingly unconstrained by the regulators.

The one exception to this rule is that banks had to comply (or appear to comply) with the international standards governing their minimum level of capital (the so-called Basle capital standards). This meant that when banks wanted to call in a non-performing loan, they were likely to have to write off existing capital, which in turn pushed them up against the minimum capital levels. The fear of falling below the capital standards led many banks to continue to extend credit to insolvent borrowers, gambling that somehow these firms would recover or that the government would bail them out.[2] Failing to

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[1] For instance, in 1997, at least 5 years after the problem of non-performing loans was recognized, the Ministry of Finance was insisting that no public money would be needed to assist the banks. In February 1999 then Vice Minister of International Finance, Eisuke Sakakibara, was quoted as saying that the Japanese banking problems "would be over within a matter of weeks." As late as 2002, the Financial Services Agency claimed that Japanese banks were well capitalized and no *more* public money would be necessary.

[2] The banks also tried to raise capital by issuing more shares and subordinated debt, as Ito and Sasaki (2002) document. When the banks raised new capital, however, almost all came from either related firms (most notably life insurance companies) that are dependent on the banks for their financing, or the

rollover the loans also would have sparked public criticism that banks were worsening the recession by denying credit to needy corporations. Indeed, the government also encouraged the banks to *increase* their lending to small and medium sized firms to ease the apparent "credit crunch" especially after 1998.[3] The continued financing, or "ever-greening," can therefore be seen as a rational response by the banks to these various pressures.

A simple measure of the ever-greening is shown in Figure 1, which reports the percentage of bank customers that received subsidized bank credit. We defer the details of how the firms are identified until the next section, but for now all that matters is that the universe of firms considered here is all publicly traded manufacturing, construction, real estate, retail, wholesale (excluding nine general trading companies) and service sector firms. The top panel of the figure shows roughly 30% of these firms were on life support from the banks in the early 2000s. The lower panel, which shows comparable asset weighted figures, suggests that about 15% of assets reside in these firms. As these figures show, these percentages were much lower in the 1980s and early 1990s.

By keeping these unprofitable borrowers (that we call "zombies") alive, the banks allowed them to distort competition throughout the rest of the economy. The zombies' distortions came in many ways, including depressing market prices for their products, raising market wages by hanging on to the workers whose productivity at the current firms declined and, more generally, congesting the markets where they participated. Effectively the growing government liability that came from guaranteeing the deposits of banks that supported the zombies served as a very inefficient program to sustain employment. Thus, the normal competitive outcome whereby the zombies would shed workers and lose market share was thwarted.[4] More importantly, the low prices and high

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government when banks received capital injections. See Hoshi and Kashyap (2004, 2005) for more on this "double-gearing" between banking and life insurance sectors.

[3] Subsequently when the Long-Term Credit Bank was returned to private ownership, a condition for the sale was the new owners would maintain lending to small and medium borrowers. The new owners tightened credit standards and the government pressured them to continue supplying funds, see Tett (2003) for details.

[4] See Ahearne and Shinada (2004) for some direct evidence suggesting that inefficient firms in the non-manufacturing sector gained market share in Japan in the 1990s. Fukao and Kwon (2006) and Nishimura, Nakajima, and Kiyota (2005) find that the productivities of the exiting firms were higher than those of the surviving firms in many industries. See also Kim (2004) and Restuccia and Rogerson (2003) for attempts to quantify the size of these types of distortions.

wages reduce the profits and collateral that new and more productive firms could generate, thereby discouraging their entry and investment.[5]   Therefore, even solvent banks saw no particularly good lending opportunities in Japan.

In the remainder of the paper we document and formalize this story. In the next section, we describe the construction of our zombie measure. There are a number of potential proxies that could be used to identify zombies. As we explain, however, measurement problems confound most of these alternatives.

Having measured the extent of zombies, we then model their effects. The model is a standard variant of the type that is studied in the literature on creative destruction. It is designed to contrast the adjustment of an industry to a negative shock with and without the presence of zombies. We model the presence of zombies as a constraint on the natural surge in destruction that would arise in the wake of an unfavorable technological, demand, or credit shock. The main effect of that constraint is that job creation must slow sufficiently to re-equilibrate the economy. This means that during the adjustment the economy is characterized by what Caballero and Hammour (1998, 2000) have called "sclerosis" — the preservation of production units that would not be saved without the banks' subsidies— and the associated "scrambling" — the retention of firms and projects that are less productive than some of those that do not enter or are not implemented due to the congestion caused by the zombies.

In the fourth section of the paper, we assess the main aggregate implications of the model. In particular, we study the interaction between the percentage of zombies in the economy and the amount of restructuring, both over time and across different sectors. We find that the rise of the zombies has been associated with falling levels of aggregate restructuring, with job creation being especially depressed in the parts of the economy with the most zombie firms. We then explore the impact of zombies on sectoral performance measures. We find that the prevalence of zombies lowers productivity.

 In section 5 we analyze firm-level data to directly look for congestion effects of the zombies on non-zombie firms' behavior. We find that investment and employment growth for healthy firms falls as the percentage of zombies in their industry rises.

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[5] It is important to clarify at the outset that the zombie mechanism complements (rather than substitutes for) standard financial constraint mechanisms. As stated in the main text, an increase in the number of zombies reduces the collateral value of good firms in the industry, and hence tightens any financial constraints.

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Moreover, the gap in productivity between zombie and non-zombie firms rises as the percentage of zombies rises. All of these findings are consistent with the predictions that zombies crowd the market and that the congestion has real effects on the healthy firms in the economy. Simple extrapolations using our regression coefficients suggest that cumulative size of the distortions (in terms of investment, or employment) is substantial. For instance, compared with the hypothetical case where the prevalence of zombies in the 1990s remained at the historical average instead of rising, we find the investment was depressed between four and 36 percent per year (depending on the industry considered).

In the final section of the paper we conclude by summarizing our results and describing their implications.

2. Identifying zombies

Our story can be divided into two parts. First, the banks misallocated credit by supporting zombie firms. Second, the existence of zombie firms interfered with the process of creative destruction and stifled growth. Our measure of zombie should not only capture the misallocation of credit but also be useful in testing the effect of zombies on corporate profitability and growth.

2.1 Defining Zombies

There is a growing literature examining the potential misallocation of bank credit in Japan (see Sekine, Kobayashi, and Saita (2003) for a survey). Much of the evidence is indirect. For instance, several papers (including Hoshi (2000), Fukao (2000), Hosono and Sakuragawa (2003), Sasaki (2004)) study the distribution of loans across industries and note that underperforming industries like real estate or construction received more bank credit than other sectors that were performing better (such as manufacturing).[6]

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[6] Other indirect evidence comes from studies such as Smith (2003), Schaede (2005) and Jerram (2004) that document that loan rates in Japan do not appear to be high enough to reflect the riskiness of the loans. Sakai, Uesugi and Watanabe (2005), however, show that poorly performing firms (measured by operating profits or net worth) still pay higher bank loan rates and are more likely to exit compared with better performing firms, at least for small firms. Finally, see also Hamao, Mei and Xu (forthcoming) who show that firm-level equity returns became less volatile during the 1990s and argue that this is likely due to a lack of restructuring in the economy.

Peek and Rosengren (2005) offer the most direct and systematic study to date on the potential misallocation of bank credit. They find that bank credit to poor performing firms often increased between 1993 and 1999. During poor performance periods, these firms' main banks are more likely to lend to them than other banks. This pattern of perverse credit allocation is more likely when the bank's own balance sheet is weak or when the borrower is a keiretsu affiliate. Importantly, non-affiliated banks do not show this pattern.

We depart from past studies by classifying firms as zombies only based on our assessment of whether they are receiving subsidized credit, and not by looking at their productivity or profitability. This strategy permits us to evaluate the effect of zombies on the economy. If instead we were to define zombies based on their operating characteristics, then almost by definition industries dominated by zombie firms would have low profitability, and likely also have low growth. Rather than hard-wiring this correlation, we want to test for it.

The challenge for our approach is to use publicly available information to determine which firms are receiving subsidized credit: banks and their borrowers have little incentive to reveal that a loan is miss-priced. Because of the myriad of ways in which banks could transfer resources to their clients, there are many ways that we could attempt to measure subsidies. To get some guidance we used the Nikkei Telecom 21 to search the four newspapers published by the Nihon Keizai Shimbun-sha (*Nihon Keizai Shimbun, Nikkei Kin'yū Shimbun, Nikkei Sangyō Shimbun, Nikkei Ryūtsū Shimbun*) between January 1990 and May 2004 for all news articles containing the words "financial assistance" and either "management reconstruction plan" or ("corporation" and "reconstruction").[7] The summary of our findings are given in Table 1.

Our search uncovers 120 separate cases. In most of them there were multiple types of assistance that were included. As the table shows, between interest rate concessions, debt-equity swaps, debt forgiveness, and moratoriums on loan principal or

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[7] The Japanese phrases were Kin'yu Shien AND (Keiei Saiken Keikaku OR (Kigyo AND Saiken)).

interest, most of these packages involve reductions in interest payments or outright debt forgiveness by the troubled firms.[8]

The decision by a bank to restructure the loans to distressed companies in these ways, rather than just rolling over the loans, helps reduce the required capital needed by the bank. Without such restructuring, banks would be forced to classify the loans to those borrowers as "at risk", which usually would require the banks to set aside 70% of the loan value as loan loss reserves. With restructuring, the banks need only move the loans to the "special attention" category, which requires reserves of at most 15%.

In light of the evidence in Table 1, we concentrate on credit assistance that involves a direct interest rate subsidy. We proceed in three steps. First, we calculate a hypothetical lower bound for interest payments (R^*) that we expect only for the highest quality borrowers. We then compare this lower bound to the observed interest payments. Finally, we make several econometric assumptions to use the observed difference between actual interest rate (r) and notional lower bound rate (r^*) to infer cases where we believe subsidies are present.

2.2 Detecting Zombies

The minimum required interest payment for each firm each year, $R^*_{i,t,}$ is defined as:

$$R^*_{i,t} = rs_{t-1}BS_{i,t-1} + \left(\tfrac{1}{5}\sum_{j=1}^{5} rl_{t-j} \right) \cdot BL_{i,t-1} + rcb_{\text{min over last 5 years},t} * Bonds_{i,t-1}$$

where $BS_{i,t}$, $BL_{i,t}$ and $Bonds_{i,t}$ are short-term bank loans (less than one year), long-term bank loans (more than one year), and total bonds outstanding (including convertible bonds (CBs) and warrant-attached bonds) respectively of firm i at the end of year t, and rs_t, rl_t, and $rcb_{\text{min over the last 5 years}, t}$ are the average short-term prime rate in year t, the

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[8] These patterns are consistent with the claim by Tett and Ibison (2001) that almost one-half of the public funds injected into the banking system in 1998 and 1999 were allowed to be passed on to troubled construction companies in the form of debt forgiveness.

average long-term prime rate in year t, and the minimum observed coupon rate on any convertible corporate bond issued in the last five years before t.

This estimate for the lower bound reflects the data constraints we face. In particular, all we know about the firms' debt structure is the type of debt instrument (short-term bank borrowing, long-term borrowing that are due in one year and remaining long-term bank borrowing, bonds outstanding that are due in one year and remaining bonds outstanding, and commercial paper outstanding). In other words, we do not know the exact interest rates on specific loans, bonds or commercial paper, nor do we know the exact maturities of any of these obligations. Finally, the interest payments we can measure include all interest, fee and discount expenses, including those related to trade credit.

The general principle guiding the choices we make is to select interest rates that are extremely advantageous for the borrower, so that R^* is in fact less than what most firms would pay in the absence of subsidies. For instance, by assuming that bond financing takes place at $rcb_{\text{min over the last 5 years, } t}$ we are assuming not only that firms borrow using convertible bonds (which carry lower interest rates due to the conversion option), but also that these bonds are issued when rates are at their lowest. We provide additional discussion of the data choices used in constructing R^* and the alternative approaches that we examined for robustness check in Appendix 1.

To categorize firms we compare the actual interest payments made by the firms ($R_{i,t}$) with our hypothetical lower bound. We normalize the difference by the amount of total borrowing at the beginning of the period ($B_{i,t-1} = BS_{i,t-1} + BL_{i,t-1} + Bonds_{i,t-1} + CP_{i,t-1}$), where $CP_{i,t-1}$ is the amount of commercial paper outstanding for the firm i at the beginning of the period t, so that the units are comparable to interest rates. Accordingly we refer to the resulting variable, $x_{i,t} \equiv \dfrac{R_{i,t} - R_{i,t}^*}{B_{i,t-1}} = r_{i,t} - r_{i,t}^*$, as the interest rate gap. This measure is "conservative" because we assume the minimum interest rates that are extremely advantageous to the firm and because the interest payment, $R_{i,t}$, includes interest expenses on items beyond our concept of total borrowing (such as interest expenses on trade credit).

Given our procedure to construct r^* we will not be able to detect all types of subsidized lending.[9] In particular, any type of assistance that lowers the current period's interest payments can be detected: including debt forgiveness, interest rate concessions, debt for equity swaps, or moratoriums on interest rate payments, all of which appeared to be prevalent in the cases studied in Table 1. On the other hand, if a bank makes new loans to a firm at normal interest rates that are then used to pay off past loans, then our gap variable will not capture the subsidy. Likewise, if a bank buys other assets from a client at overly generous prices our proxy will not detect the assistance.

We explore two strategies for identifying the set of zombie firms from the calculated interest rate gaps. Our baseline procedure classifies a firm i as a zombie for year t whenever its interest rate gap is negative ($x_{it} < 0$). The justification for this strategy is the conservative philosophy underlying the construction of r^*. If r^* is a perfectly measured lower bound, then only a firm that receives a subsidy can have a negative gap. However, the problem of labeling a firm with x_{it} just above zero as non-zombie remains even under this perfect scenario.

Thus we resort to a second approach, which is more robust to misclassification of non-zombies. In this second approach we assume that the set of zombies is a "fuzzy" set. In the classical set theory, an element either belongs or does not belong to a particular set so that a 0-1 indicator function can be used to define a subset. In contrast, in fuzzy set theory an element can belong to a particular subset to a certain degree, so that the indicator function can take any value in the interval [0, 1]. When the images of the indicator function are confined to {0, 1}, a set defined by the indicator function is called a "crisp" set. Using this terminology, our first approach assumes the set of zombies is "crisp." Our second approach, on the other hand, assumes the set is "fuzzy," allowing some firms to be more-or-less zombie-like.[10]

The indicator function that defines a fuzzy subset is called "membership function," which we assume to be (for the set of zombie firms):

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[9] In addition to the cases studied below, Hoshi (2006) examines the potential problems that might arise from rapid changes in interest rates. For example, if interest rates fell sharply and actual loan terms moved as well, then our gap variable could be misleading about the prevalence of subsidized loans. He constructs an alternative measure (that would be more robust to within year interest rate changes) and concludes that this sort of problem does not appear to be quantitatively important.

[10] See Nguyen and Walker (2006) for an introduction to the fuzzy set theory.

$$z(x;d_1,d_2) = \begin{cases} 1 & \text{if } x < d_1 \\ \dfrac{d_2 - x}{d_2 - d_1} & \text{if } d_1 \leq x \leq d_2 \quad \text{where } d_1 \leq 0 \leq d_2 \\ 0 & \text{if } x > d_2 \end{cases} \qquad (1)$$

The shape of the membership function is determined by the two parameters, d_1 and d_2. Figure 2 shows this membership function along with the indicator function implicit in our first approach. It is easy to see the second approach degenerates to our first approach when d_1 and d_2 are both zero.

The second approach is appealing given the fuzzy nature of the concept of "zombie firms." These are defined to be those firms that receive sufficient financial help from their creditors to survive in spite of their poor profitability. It is inherently difficult to specify how much financial help is considered to be sufficient, even if we had access to much more information than we do about individual firms. Our fuzzy approach acknowledges this limitation and assigns numbers between 0 and 1 to those firms whose zombie status is ambiguous.

Given the asymmetry (toward conservatism) inherent in the construction of r^*, we assume that d_1 is closer to zero than d_2. In what follows we show results for $(d_1, d_2) = (0, 50\text{bp})$ and $(d_1, d_2) = (-25\text{bp}, 75\text{bp})$, where bp stands for basis points. Thus, in the first case, we assume a firm with x_{it} below zero is a definite zombie and a firm with x_{it} above 50 basis points is definitely a non-zombie: any firm with x_{it} between zero and 50 basis points has "zombiness" between 0 and 1.

2.3 Quantifying the prevalence of zombies

Figure 1 showed the aggregate estimate of the percentage of zombies using our baseline procedure. As mentioned earlier, treating all firms equally we see that the percentage of zombies hovered between 5 and 15 percent up until 1993 and then rose sharply over the mid 1990s so that the zombie percentage was above 25 percent for every year after 1994. In terms of congestion spillovers, a size weighted measure of zombies is likely to be more important. Weighting firms by their assets we see the same general

pattern but with the overall percentage being lower, closer to 15 percent in the latter part of the sample.

We view the cross-sectional prevalence of zombies as another way to assess the plausibility of our definition. To conduct this assessment, we aggregated the data used in Figure 1 into five industry groups covering manufacturing, construction, real estate, retail and wholesale (other than the nine largest general trading companies), and services – recall that all the firms included here are publicly traded. The zombie index for an industry is constructed by calculating the share of total assets held by the zombie firms – and for the remainder of the paper we concentrate on asset weighted zombie indices. In addition to showing the industry distribution, we also compute the zombie percentages implied by our second procedure with $(d_1, d_2) = (0, 50bp)$ and $(d_1, d_2) = (-25bp, 75bp)$.

Figure 3 shows the zombie index for each industry from 1981 to 2002. We draw three main conclusions from these graphs. Starting with the upper left hand panel that shows the data for the entire sample, first notice that the crisp zombie measure (our baseline case) and the two fuzzy measures share similar time series movements (with the correlation between the crisp measure and the two fuzzy measures exceeding 0.99). Second, the other five panels show that the proportion of zombie firms increased in the late 1990s in every industry. The third key conclusion is that the zombie problem was more serious for non-manufacturing firms than for manufacturing firms. In manufacturing, the crisp measure suggests that zombie index only rose from 3.11% (1981-1993 average) to 9.58% (1996-2002 average). In the construction industry, however, the measure increased from 4.47% (1981-1993 average) to 20.35% (1996-2002 average). Similar large increases occurred for the wholesale and retail, services, and real estate industries.

There are a variety of potential explanations for these cross-sectional differences. For instance, Japanese manufacturing firms face global competition and thus could not be protected easily without prohibitively large subsidies. For example, many of the troubled Japanese automakers were taken over by foreign firms rather than rescued by their banks during the 1990s. In contrast, there is very little foreign competition in the other four industries.

A second important factor was the nature of the shocks hitting the different sectors. For instance, the construction and real estate industries were forced to deal with the huge run-up and subsequent collapse of land prices mentioned earlier. Thus, the adjustment for these industries was likely to be more wrenching than for the other sectors.

But the most important point about the differences shown in Figure 3 is that they confirm the conventional wisdom that bank lending distortions were not equal across sectors and that the problems were less acute in manufacturing – see Sekine et al (2003) for further discussion. Thus, regardless of which explanation one favors as to why this might be the case, we view it as particularly reassuring that our zombie index confirms this conventional view.

Figure 4, our last plausibility check, shows the asset weighted percentages of zombies for the firms that are above and below the median profit rate for their industry. To keep the graphs readable we show only the crisp measures, but the other measures show similar patterns. In manufacturing the differences are not very noticeable, with slightly fewer high profit firms being labeled as zombies. In the remaining industries, particularly in real estate and construction, it appears that our measure of zombies is identifying firms that are systematically less profitable than the non-zombies, particularly from the mid-1990s onward.

2.4. Potential Classification Errors

Our classification scheme of zombies is admittedly imperfect, so we also consider a number of alternative schemes. The goal in exploring these alternatives is to assess the effect of misclassifying a zombie firm as a non-zombie (a type I error) or misclassifying a healthy firm as a zombie (a type II error). Most of the alternatives reduce one type of error by increasing the other type of error. Thus, we do not expect the results from these experiments to be identical. Instead, we looked primarily at whether the time series pattern and cross-sectional patterns were similar to the ones presented in the last section. We also re–estimate our basic regressions using these alternative zombie measures instead of our standard measures. The results for the baseline definitions and the

alternatives are generally quite similar, and in the remainder of this section we briefly describe the properties of the alternatives.

One possible problem is that some good firms are mistakenly dubbed zombies because they can borrow at interest rates lower than the prime rates. Alternatively, if a good firm pays off its bank loans during an accounting year, we may find its interest payment for the accounting year too small given the amount of bank loans at the beginning of the period and classify the firm as a zombie.[11]

To gauge the extent of these problems we modified our baseline definitions in two ways (both of which will reduce our estimates of the zombie prevalence). In one version, we automatically classified any firms with quality corporate bonds as non-zombies. This makes sense if we believe buyers of bonds will not subsidize firms and hence access to the bond market would dry up for failing firms. We considered two thresholds: bonds rated A or above, or those rated BBB or above, the latter being the cutoff for a bond to be considered investment grade.[12]

We also modified the definition to use data from either two or three years to determine a firm's zombie status; in these alternatives, we average the value of the zombie indicators across either two or three years. By taking only the firms that have persistently low funding costs we are much more likely to avoid incorrectly labeling a non-zombie as a zombie. However, given the nature of the lower bound interest rate used in our calculation, this averaging would be extremely conservative and hence much more likely to characterize zombies as non-zombies.[13]

To explore the potential impact of these type I errors, we reverse the preceding logic and count firms as zombies based on the maximum zombie indicator over either the

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[11] To see how often clearly healthy firms are mis-classified as zombies by our crisp definition, Hoshi (2006) examined the firms that had R&I bond rating of AA or above as of November 2004 and are included in our sample. In only one occasion for one out of these 26 firms for five years (1997 to 2001), our zombie index misclassified the firm as a zombie. From this, he concludes the type II error is not a serious problem.

[12] We use the Ratings by R&I and its predecessors. We thank Yasuhiro Harada and Akio Ihara of R&I for providing us with the data. When both the firm itself and the bonds that the firm issued are rated, we use the rating for the firm. When the rating for the firm itself is not available and when multiple bonds are rated, we use the most recent rating announcement (newly rated, changed, or maintained).

[13] If we go all the way to forcing the firms to be obvious zombies in multiple consecutive years the percentages of zombies drops sharply. For instance, using the crisp definition, the percentage of assets in zombies firms is 14.96% in 2002. If we consider only firms that are zombies in two (three) consecutive years, the percentage drops to 10.83% (8.74%).

last two or three years.[14] For example, with the three year window, we define a new crisp set of zombies that include all firms for which the crisp indicator identifies a firm as a zombie in the current year or either of the last two years. Naturally, these corrections raise the estimated prevalence of zombies.

Collectively these experiments yield 18 alternative indices (the three baseline definitions, interacted with two different bond rating thresholds, two time averaging schemes, and two maximum time horizons).   Table 2 summarizes the characteristics of the various definitions.   The second column shows the correlations between the different measures and the crisp index (Z1), while the next column reports the asset weighted percentage of zombies in the last year of the sample (2002). We report the latter data because having inspected versions of Figure 3 for the various definitions, this is a convenient way to summarize the quantitative differences across them.

We read these two columns as suggesting two main conclusions. First, the crisp measure is highly correlated with all other measures.   Second, the quantitative significance of the alternatives on the estimated level of zombie prevalence is fairly modest. For instance, the estimates for the conservative alternatives based on the crisp zombie definition (ZA01 to ZA04) in 2002 range from 10.65% to 14.14%, while Z01 is 14.96%. The estimates for the alternatives based on fuzzy zombies (ZA05 to ZA12) range between 17.09% and 22.17%, while Z02 and Z03 are 21.40% and 22.42%, respectively.

The remaining columns in the table show correlations between the crisp measure for different industries and the alternative estimates.   Given the predominance of manufacturing firms in the sample it is not surprising that the results for that industry mimic the full sample patterns. The alternatives are also quite similar for construction, trade and services, and there is no reason why this needs to be the case.

The variation across the zombie definitions for the real state sector is somewhat larger. This partially reflects the fact that there were not many real estate firms in the sample (fewer than 40 in the early 1980s and no more than 60 during the 1990s). Indeed,

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[14] Hoshi (2006) examines prevalence of type I error by looking at how our zombie measure classifies well known troubled firms in Japan. He finds that our measure often fails to identify the firms in the list of highly indebted and troubled firms published in *Kin'yu Business* (December 2001) as zombies. Thus, he concludes the type I error is potentially a problem.

looking back at Figure 3 it was already apparent that the fuzzy and crisp definitions gave somewhat different pictures of the 1980s. This is because the movement of only a few firms could change the percentages appreciably. Fortunately given the small size of this sector relative to the other four (less than 5% of total sample assets reside in this sector), these differences are not responsible for the main findings that follow.

3. A simple model of the effect of zombie firms on restructuring

To analyze the effect of zombies we study a simple environment that involves entry and exit decisions of single-unit incumbent firms and potential new firms. After exploring this case we consider a richer version of the model that describes expansion and contraction decisions of existing multi-unit firms. As a benchmark we first model all decisions being governed purely by the operating profits from running a firm. We then contrast that environment to one where some incumbent firms (for an unspecified reason) receive a subsidy that allows them to remain in business despite negative operating profits.

3.1 The Environment

The essential points of interest can be seen in a model where time is discrete and indexed by t. A representative period t starts with a mass m_t of existing production units. The productivity of the incumbents varies over time and the current level of productivity for firm i in year t, Y_{it}^o, is:

$$Y_{it}^o = A_t + A_t B + A_t \varepsilon_{it}^o = A_t(1 + B + \varepsilon_{it}^o),$$

where A_t represents the state of technology shared by all the incumbent production units at time t, B is a potential shift parameter that can represent an aggregate productivity shock, and ε_{it}^{o} is an idiosyncratic shock that is distributed uniformly on the unit interval. The state of technology is assumed to improve over time so that $A_{t+1} > A_t$. The main predictions from this model do not depend on the persistence of idiosyncratic productivity shocks, so we assume they are independently and identically distributed.

In addition to the incumbents, there is also a set of potential entrants, and we normalize their mass to be ½. Each potential entrant draws a productivity level, Y_{it}^{n}, before deciding whether to enter or not. We assume that potential entrants have technological advantage over incumbents, so that the productivity for a potential new firm is consistently higher than incumbents by γA_t. Thus,

$$Y_{it}^{n} = A_t(1 + \gamma) + A_t B + A_t \varepsilon_{it}^{n} = A_t(1 + \gamma + B + \varepsilon_{it}^{n})$$

with ε_{it}^{n} distributed uniformly on the unit interval. The shock ε_{it}^{n} is again assumed to have no persistence. The stochastic process for aggregate technology left unspecified, except for the assumption that it grows by more than the advantage of the new firms, so that $A_{t+1} > (1+\gamma)A_t$. We also assume that there is an entry cost that is proportional to the state of technology, $\kappa A_t > 0$, that the new entrants must pay to start up.

Finally, both new and old units must incur a cost $A_t p(N_t)$ in order to produce, where N_t represents the number of production units in operation at time t, i.e., the sum of remaining incumbents and new entrants. The function $p(N)$ is increasing with respect to N, and captures any reduction in profits due to congestion or competition.[15] For our purposes, all the predictions we emphasize will hold as long as $p(N)$ is a strictly increasing continuous function of N. For simplicity, we adopt the linear function:

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[15] For example, we can motivate *p(N)* as the reduction in profits due to competition in the output market. Suppose the price of output is given by $D^{-1}(N)$, a decreasing function of *N*, and that the cost of production for each production unit is just proportional to the state of technology, *AC*. Under our assumption on productivity, an incumbent decides to stay in the market (and a potential entrant decides to enter the market) if $D^{-1}(N)A(1+B+\varepsilon) - AC > 0$, or equivalently, $1+B+\varepsilon - C/D^{-1}(N) > 0$. In this specific example, *p(N)* is $C/D^{-1}(N)$, which is increasing with respect to *N*.

$$p(N_t) = N_t + \mu.$$

where the intercept μ captures cost changes and other profit shocks.

In analyzing this model, it is useful to normalize productivity by the state of technology. For the incumbents, this is given by:

$$y_{it}^o \equiv \frac{Y_{it}^o}{A_t} = 1 + B + \varepsilon_{it}^o \tag{2}$$

For the potential entrants:

$$y_{it}^n = \frac{Y_{it}^n}{A_t} = 1 + \gamma + B + \varepsilon_{it}^n \tag{3}$$

3.2 Decisions

This basic model will quickly generate complicated dynamics because the existing firms have paid the entry cost and thus face a different decision problem than the new firms for which the entry cost is not sunk. These dynamics are not essential for our main predictions, thus we assume that $\gamma = \kappa$. In this case, the exit decision by incumbents and the entry decision by potential entrants become fully myopic. Since productivity shocks are i.i.d. and there is no advantage from being an insider (the sunk cost of investment is exactly offset by a lower productivity), both types of units look only at current profits to decide whether to operate.

Letting $\bar{y}^o$ and $\bar{y}^n$ denote the reservation productivity (normalized by the state of technology) of incumbents and potential entrants, respectively, we have:

$$\bar{y}^o - p(N) = 0,$$

$$\bar{y}^n - \kappa - p(N) = 0.$$

In this case it is straightforward to find the mass of exit, D_t, and entry, H_t, respectively:

$$D_t = m_t \left[1 - \int_{p(N_t)-1-B}^{1} di \right] = m_t (p(N_t) - 1 - B), \qquad (4)$$

$$H_t = \frac{1}{2} \int_{p(N_t)-1-B}^{1} di = \frac{1}{2} (1 - (p(N_t) - 1 - B)). \qquad (5)$$

Adding units created to the surviving incumbents yields the total number of units operating at time t :

$$N_t = H_t + m_t - D_t = \left(\frac{1}{2} + m_t \right) \left(1 - (p(N_t) - 1 - B) \right). \qquad (6)$$

3.3 Equilibrium and Steady State

We can now solve for the steady state of the normal version of the economy. The first step is to replace $p(N)$ with $N + \mu$ in (6). The notation is simplified if we define S to be composite shock that is equal to $1+B-\mu$. Note that a lower S indicates either higher costs (higher μ) or lower productivity for both incumbents and potential entrants (smaller B). We can now find the equilibrium number of units:

$$N_t = \left(\frac{1/2 + m_t}{3/2 + m_t} \right) (1 + S). \qquad (7)$$

Given the total number of operating units, we can solve for equilibrium rates of destruction and creation by substituting (7) into (4) and (5):

$$D_t = m_t \left(\frac{1/2 + m_t - S}{3/2 + m_t} \right) \qquad (8)$$

$$H_t = \frac{1}{2} \left(\frac{1 + S}{3/2 + m_t} \right). \qquad (9)$$

The dynamics of this system are determined by:

$$m_{t+1} = N_t. \tag{10}$$

In steady state, the mass of incumbents remains constant at $m^{ss} = N^{ss}$, which requires that creation and destruction exactly offset each other or, equivalently, that $m_t = N_t$. Using the latter condition and (7), yields a quadratic equation for m^{ss}, which has a unique positive solution of:

$$m^{ss} = \frac{S - \frac{1}{2} + \sqrt{\left(\frac{1}{2} - S\right)^2 + 2(1+S)}}{2}$$

For small values of S, we can approximate the above by:

$$m^{ss} \approx \frac{1}{2} + \frac{2}{3}S.$$

In our subsequent analysis we will assume that the economy begins in a steady state and that the initial (pre-shock) value of S, S_0, is 0. Given this normalization, the corresponding steady state will be $m_0 = N_0 = 1/2$ and $H_0 = D_0 = 1/4$.

3.4 A (permanent) Recession

We can now analyze the adjustment of the economy to a profit shock. By construction the model treats aggregate productivity shifts, changes in A, and cost shocks, changes in µ, as equivalent. Thus, what follows does not depend on which of these occurs. We separate the discussion to distinguish between the short- and long-run impact of a decline in S from $S_0 = 0$ to $S_1 < 0$. By the "short-run" we mean for a fixed $m = m_0 = 1/2$. By the "long-run," on the other hand, we mean after m has adjusted to its new steady state value $m_1 = 1/2 + (2/3)S_1$.

It is easy to see from the equations (7), (8) and (9) that in the short-run:

$$\frac{\partial D}{\partial S} = \frac{-2m_0}{3+2m_0} = -\frac{1}{4} \tag{11}$$

$$\frac{\partial H}{\partial S} = \frac{1}{3+2m_0} = \frac{1}{4} \tag{12}$$

$$\frac{\partial N}{\partial S} = \frac{1+2m_0}{3+2m_0} = \frac{1}{2} \tag{13}$$

That is, when S drops, creation falls and destruction rises, leading to a decline in N. In other words, in a normal economy, a negative profit shock is met with both increased exit by incumbents and reduced entry of new firms.

Over time, the gap between destruction and creation reduces the number of incumbents (recall from (6) and (10) that $\Delta N = H - D$), which lowers the cost ($p(N)$) and eventually puts an end to the gap between creation and destruction caused by the negative shock.

Across steady states, we have that:

$$\frac{\partial N}{\partial S} = \frac{\partial m}{\partial S} = \frac{2}{3}$$

The number of production units falls beyond the initial impact as time goes by and the positive gap between destruction and creation closes gradually. Note that because N falls less than one for one with S, the long run reduction in the cost due to reduced congestion is not enough to offset the direct effect of a lower S on creation. That is, creation falls in the long run. And since creation and destruction are equal in the long run, the initial surge in destruction is temporary and ultimately destruction also ends up falling below its pre-shock level.[16]

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[16] This long run level effect is undone when creation and destruction are measured as ratios over N, as is often done in empirical work. However, the qualitative aspects of the short run results are preserved since

3.5 Zombies

Suppose now that "banks" choose to protect incumbents from the initial surge in destruction brought about by the decline in S. There are a variety of ways that this might be accomplished. We assume that the banks do this by providing just enough resources to the additional units that would have been scrapped so that they can remain in operation. With this assumption, a firm that does receive a subsidy is indifferent to exiting and operating, and thus entry and exit decisions remain myopic.

Under the zombie-subsidy assumption, we have that:

$$D_{0+}^z = D_0 = \frac{1}{4}.$$

The post-shock destruction remains the same as the pre-shock level. The lack of adjustment on the destruction margin means that now creation must do all the adjustment. Thus, the following two equations, derived from (5) and (6), determine the post-shock creation and the number of production units under the presence of zombies.

$$H_{0+}^z = \frac{1}{2}(1 - N_{0+}^z + S)$$

$$N_{0+}^z = H_{0+}^z + m_0 - D_{0+}^z = H_{0+}^z + 1/4$$

Solving these:

$$H_{0+}^z = \frac{1}{3}(1 + S) - \frac{1}{3}(m_0 - D_{0+}^z) = \frac{S}{3} + \frac{1}{4} \tag{14}$$

$$N_{0+}^z = \frac{1}{3}(1 + S) + \frac{2}{3}(m_0 - D_{0+}^z) = \frac{S}{3} + \frac{1}{2} \tag{15}$$

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empirically the flows are divided by either initial employment or a weighted average of initial and final employment.

Differentiating (14) with respect to S, and compare the result to the short-run change in creation that occurs in the absence of zombies (given by (12)):

$$\frac{\partial H_{0+}^z}{\partial S} = \frac{1}{3} > \frac{1}{4} = \frac{\partial H_{0+}}{\partial S}.$$

Indeed, it is easy to see the expression (12) is less than 1/3 for any positive m_0. That is, a decline in S always has a much larger negative effect on creation in the presence of zombies. This result is a robust feature of this type of model. In particular, the same qualitative prediction would hold even if we had not suppressed the dynamics and had allowed persistence in the productivity shocks and a gap between entry costs and the productivity advantage of new firms. Intuitively, this is the case because the adverse shock requires the labor market to clear with fewer people employed. If destruction is suppressed, then the labor market clearing can only occur if job creation drops precipitously.

As Caballero and Hammour (1998, 2000) emphasize, both this "sclerosis" — the preservation of production units that would not be saved without the banks' subsidies— and the associated "scrambling" — the retention of firms that are less productive than some of those that do not enter due to the congestion caused by the zombies – are robust implications of models of creative destruction when there are frictions against destruction.

Compared with a normally functioning economy, we have shown the existence of zombies softens a negative shock's impact on destruction and exacerbates its impact on creation. What is the net effect on the number of firms? Differentiating (15) with respect to S:

$$\frac{\partial N_{0+}^z}{\partial S} = \frac{1}{3} < \frac{1}{2} = \frac{\partial N_{0+}}{\partial S}.$$

That is, in response to a negative shock, N falls by less if there are zombies, which means that in the presence of zombies the reduced destruction is not fully matched by the additional drop in creation. It is easy to see that the expression (13) is greater than 1/3 for

any positive m_0. This is another intuitive and robust result. This occurs because as job creation falls, the marginal entrant's productivity rises. This high productivity allows the marginal entrant to operate despite the higher cost induced by (comparatively) larger N.

A final important prediction of the model is the existence of a gap in profitability (net of entry costs) between the marginal entrant and the marginal incumbent when there are zombies.[17] At impact, the destruction does not change, so that all the firms with idiosyncratic productivity shocks above the old threshold (1/2) remain in the industry. On the other hand, new entrants have to clear a higher threshold to compensate for the negative shock in S (which is only partially offset by the lower congestion following the negative shock). As a result, the profitability of the marginal entrant is inefficiently higher than that of the marginal incumbent. The difference (normalized by the existing state of technology) is given by:

$$\left[\left(\frac{S}{3} + \frac{1}{2} \right) - S \right] - \frac{1}{2} = -\frac{2}{3} S > 0.$$

In summary, the model makes two robust predictions. The first is that the presence of zombies distorts the normal creation and destruction patterns to force larger creation adjustments following shocks to costs, productivity or profits. Second, this distortion depresses productivity by preserving inefficient units at the expense of more productive potential entrants.   Accordingly, productivity will be lower when there are more zombies and as the zombies become more prevalent they will generate larger and larger distortions for the non-zombies.

Finally, note that for simplicity we have illustrated the main effects of zombies in the case of a permanent recession. However these effects carry over to temporary recessions as well. The main mechanism through which zombies hurt creation and productivity is through congestion. It is apparent that if the recession were to end, then the presence of congesting zombies would yield a recovery that is less vigorous in terms

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[17] Note that a wedge like this one also arises when there is a credit constraint on potential entrants but not on incumbents. In our model depressed entry results from the congestion due to zombies, and the gap is due to the subsidy to incumbents. Clearly, however, if the two mechanisms coexist they would reinforce each other, as congestion would reduce the collateral value of potential entrants.

of creation and productivity growth. This weak recovery aspect is also a fairly general implication of models of creation destruction with frictions in destruction.[18]

3.6. A Firm as a Collection of Projects

By re-interpreting a "production unit" in the model to be a "project" and defining a "firm" as an entity that has many such projects (both existing and potential), we can use the model to discuss expansions and contractions of large firms. This extension brings the theoretical discussion closer to our empirical analysis in later sections.

Let us assume that the industry has a fixed number of firms, which is normalized to be one. Each firm has a mass m_{kt} of incumbent projects, whose productivity (normalized by the existing state of technology) is given by (2). Each firm has a mass 1/2 of potential new projects, whose productivity (normalized by the state of technology) is given by (3). Each project is hit by an idiosyncratic shock every period, so each firm decides which incumbent projects to terminate and which new projects to start.

A zombie firm is defined to be a firm that does not adjust the project selection rules when a (negative) shock hits the industry, consistent with the discussion above. A non-zombie firm adjusts the project selection rules following the shock. The operating cost (normalized by the state of technology) of the firm is assumed is, as before, a function of the total amount of projects operated by all the firms in the industry at time t, N_t. Letting λ be the proportion of non-zombie firms in the industry and assuming all zombies (and non-zombies) are homogeneous within the group in terms of the distribution of potential projects they can take, the total number of projects actually taken by all the firms is:

$$N_t = \lambda N_t^{nz} + (1-\lambda)N_t^z, \qquad\qquad\qquad (16)$$

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[18] See, e.g., Caballero (2007).

where N_t^z is the total number of projects operated by a (representative) zombie firm and N_t^{nz} is the total number of projects operated by a (representative) non-zombie firm.

Assuming the same linear functional form for *p(N)* and the same notation for the shock *S* as in the previous sections, a non-zombie firm starts all the new projects with idiosyncratic productivity shock greater than *N-S* and terminates all the incumbent projects with idiosyncratic productivity shock less than *N-S*. Thus, destruction (the number of incumbent projects terminated) by non-zombies, denoted by D_t^{nz} is:

$$D_t^{nz} = m_t^{nz}(N_t - S), \tag{17}$$

where m_t^{nz} is the number of incumbent projects for a non-zombie at the beginning of period *t*. Similarly, creation (the number of new projects implemented) by non-zombies, denoted by H_t^{nz} is:

$$H_t^{nz} = \frac{1}{2}(1 + S - N_t) \tag{18}$$

The total number of projects taken by non-zombie firms in period *t* is:

$$N_t^{nz} = m_t^{nz} + H_t^{nz} - D_t^{nz} \tag{19}$$

Solving the equations (16) through (19) for a given N_t^z, which by assumption is insensitive to changes in *S*,

$$N_t^{nz} = \frac{1/2 + m_t^{nz}}{1 + \lambda(1/2 + m_t^{nz})}\left[1 + S - (1-\lambda)N_t^z\right] \tag{20}$$

$$D_t^{nz} = \frac{m_t^{nz}}{1 + \lambda(1/2 + m_t^{nz})}\left[\lambda\left(\frac{1}{2} + m_t^{nz}\right) - S - \left\{\lambda\left(\frac{1}{2} + m_t^{nz}\right) - 1\right\}(1-\lambda)N_t^z\right] \tag{21}$$

$$H_t^{nz} = \frac{1}{2\left(1 + \lambda(1/2 + m_t^{nz})\right)}\left[1 + S - (1 - \lambda)N_t^z\right]$$

(22)

By differentiating (20), (21), and (22), it is straightforward to see:

$$\frac{\partial D_t^{nz}}{\partial S} = -\frac{m_t^{nz}}{1 + \lambda(1/2 + m_t^{nz})} < 0$$

$$\frac{\partial H_t^{nz}}{\partial S} = \frac{1/2}{1 + \lambda(1/2 + m_t^{nz})} > 0$$

$$\frac{\partial N_t^{nz}}{\partial S} = \frac{1/2 + m_t^{nz}}{1 + \lambda(1/2 + m_t^{nz})} > 0$$

Thus, following a negative profitability shock, non-zombie firms increase destruction, reduce creation, and contract. Moreover, the size of these adjustments is increasing in the number of zombies in the industry. This can be shown by differentiating the derivatives above with respect to λ.

$$\frac{\partial^2 D_t^{nz}}{\partial S \partial \lambda} = \frac{m_t^{nz}(1/2 + m_t^{nz})}{\left[1 + \lambda(1/2 + m_t^{nz})\right]^2} > 0$$

$$\frac{\partial^2 H_t^{nz}}{\partial S \partial \lambda} = -\frac{(1/2 + m_t^{nz})}{2\left[1 + \lambda(1/2 + m_t^{nz})\right]^2} < 0$$

(23)

$$\frac{\partial^2 N_t^{nz}}{\partial S \partial \lambda} = -\frac{(1/2 + m_t^{nz})^2}{\left[1 + \lambda(1/2 + m_t^{nz})\right]^2} < 0$$

Having more zombies in the industry (smaller λ) increases the amount of adjustment induced by a negative shock (negative S).

We can also study the productivity implications for non-zombies. The productivity (normalized by the state of technology) of the marginal incumbent project kept by non-zombie firms is $N_t - S$. Similarly, the productivity of the marginal new project chosen by non-zombies is $\gamma + N_t - S$. Thus, under the assumption of a uniform

distribution of idiosyncratic shock for projects, the average productivity of a non-zombie firm, V_t, is:

$$V_t = \frac{1 + N_t - S}{2} + \frac{\gamma}{2} \frac{H_t^{nz}}{N_t^{nz}} \qquad (24)$$

Substituting (16), (20), and (22) into (24), yields:

$$V_t = \frac{1 + (1 - \lambda)N_t^z + \lambda N_t^{nz} - S}{2} + \frac{\gamma}{2(1 + 2m_t^{nz})}$$

Thus,

$$\frac{\partial V_t}{\partial S} = \frac{1}{2}\left[\lambda \frac{\partial N_t^{nz}}{\partial S} - 1\right] - \frac{\gamma}{(1 + 2m_t^{nz})^2} \frac{\partial m_t^{nz}}{\partial S}$$

$$= -\frac{1}{2 + \lambda(1 + 2m_t^{nz})} - \frac{\gamma}{(1 + 2m_t^{nz})^2} \frac{\partial m_t^{nz}}{\partial S} \qquad (25)$$

Immediately after a negative profitability shock hits the industry, the second term of this expression is zero, so that the average productivity of a non-zombie unambiguously goes up.

Over time, a negative shock reduces the number of incumbent projects and gradually increases the proportion of new (and more productive) projects relative to incumbent projects. This further increases average productivity.

$$\cdot \frac{\partial m_t^{nz}}{\partial S} = \frac{\partial N_{t-1}^{nz}}{\partial S} = \frac{1/2 + m_{t-1}^{nz}}{1 + \lambda(1/2 + m_{t-1}^{nz})} > 0$$

Moreover, it is clear that both (negative) terms in (25) are increasing in λ. Thus, when there are more zombies in the industry (smaller λ), the size of the productivity gap increases.

From this analysis we conclude that allowing for multi-project firms does not change the baseline predictions regarding creation, destruction or productivity. We explored further extensions of the model that allowed for heterogeneity in the productivity levels but found that there were no robust predictions about how heterogeneity might alter these predictions. In particular, if we model heterogeneity as a firm specific factor that affects the level of productivity (i.e. adding a firm-specific constant to equations (2) and (3)), then there are no changes to our main predictions regarding the effects of increased zombie prevalence.

4. The effect of zombies on job creation, destruction and productivity

We use the two robust predictions of the model to guide our search for evidence that the zombie problem has affected Japan's economic performance significantly. We begin by looking at aggregate cross-industry differences. In the next section, we study firm-level data to characterize how the behavior of the non-zombie firms has been altered by the presence of zombie competitors.

Because our zombie indices exist from 1981 onwards, we start by calculating the average of the crisp zombie index for each industry from then until 1993 and compare that to the average for the late 1990s (1996-2002). We use the differences in these two averages to correct for possible biases in the level of zombie index and any industry-specific effects. It makes little difference as to how we define the pre-zombie period. In particular, the results we show would be very similar if we took the normal (non-zombie) period to be 1981 to 1990, or 1990 to 1993. Our evidence consists of relating creation, destruction, and productivity data to this change in the zombie index, in order to see if these measures are more distorted in the industries where zombie prevalence has increased the most.

Our most direct evidence on this point is in Figure 5, which plots the rate of job creation and destruction against the change in the zombie index. We use the job flow measures constructed by Genda et al. (2003) as proxies for the concepts of entry and exit in our model. Their measures are based on The Survey of Employment Trends, conducted by the Ministry of Welfare and Labor biannually on a large sample of

establishments that employ five or more regular workers. The series used for our analysis include not only the job creation (destruction) at the establishments that were included in the survey in both at the beginning and at the end of the year, but also the estimated job creation (and destruction) by new entrants (and the establishments that exited). To control for the industry specific effects in job creation/destruction, we look at the difference between the average job creation (destruction) rate for the 1996-2000 period and the average for the 1991-1993 period. We are restricted to using the 1991—93 data as a control because figures of Genda et al. start only in 1991 and we stop in 2000 because that is the last year they cover.

The top of Figure 5 shows that the job destruction rate in the late 1990s increased from that in the early 1990s in every industry, as we would expect to see following an unfavorable shock to the economy.[19] More importantly, the graph shows that the surge in destruction was smaller in the industries where more zombies appeared. Thus, as we expected, the presence of zombies slows down job destruction.

The second panel of Figure 5 shows that the presence of zombies depresses job creation. Creation declined more in the industries that experienced sharper zombie growth. In manufacturing, which suffered the least from the zombie problem, job creation hardly changed from the early 1990s to the late 1990s. In sharp contrast, job creation exhibits extensive declines in non-manufacturing sectors, particularly in the construction sector.

Of course not all sectors were equally affected by the Japanese crash in asset prices and the slowdown that followed it. For example, construction, having benefited disproportionately from the boom years, probably also was hit by the largest recessionary shock during the 1990s. A large shock naturally raises job destruction and depresses job creation further. Despite this source of (for us, unobserved) heterogeneity, the general patterns we expected from job flows hold. One way of controlling for the size of the shock is by checking whether in more zombie-affected sectors, the *relative* adjustment through job creation is larger. In this metric, it is quite clear from Figure 5 that job

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[19] Our simple model assumes that the job destruction rate stays the same even after a negative shock in a zombie industry. It is straightforward to relax this by assuming, for example, that 90% of zombies are rescued by banks. None of the major results would change. Job destruction would rise following a negative shock but not as much as it would under the normal environment.

creation has borne a much larger share of the adjustment in construction than in manufacturing.

Our evidence on productivity distortions caused by the interest rate subsidies is given in Figure 6. In the model, zombies are the low productivity units that would exit the market in the absence of help from the banks. Their presence lowers the industry's average productivity both directly by continuing to operate and indirectly by deterring entry of more productive firms. The productivity data here are from Miyagawa, Ito and Harada (2004) who study productivity growth in 22 industries. Figure 6, which plots the average growth of the total factor productivity (TFP) from 1990 to 2000 against the change in the crisp zombie index, shows that the data are consistent with the model's implication: the regression line in the figure confirms the visual impression that industries where zombies became more important were the ones where TFP growth was worst.[20]

As mentioned in the introduction to the paper, the role of zombie firms in depressing   productivity is a critical channel through which zombies can have longer-lived aggregate affects. One potential concern with the causal interpretation of Figure 6 is that the zombie infestation was most pronounced outside of manufacturing and it is possible that the lagging productivity of these industries is just a normal cyclical phenomenon.

 Figure 7 shows the (level of) TFP for the manufacturing sector and non-manufacturing sector from 1980 through 2004.[21] The data are taken from the EU Klems project (http://www.euklems.net/) that is organized by the European Union and the OECD to permit comparisons of productivity and other economic outcomes across countries. We form the non-manufacturing series by weighting the reported valued added TFP figures for Construction, Wholesale and Retail Trade, and Real Estate Activities by their value added shares.[22] The shaded areas of the graph show business cycle downturns, defined as the period between a peak and the next official business cycle trough (http://www.esri.cao.go.jp/en/stat/di/041112rdates.html).

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[20] Of course this correlation could arise because industries that had the worst shocks wound up with the most zombies. We can disentangle these explanations by using firm-level data (see below).
[21] Prior to 1980 manufacturing productivity growth in Japan was exceptionally high (presumably due to the catching up of the Japanese economy). Hence, comparisons of manufacturing and non-manufacturing productivity in the 1970s and 1960s are not informative about the issues that interest us.
[22] In the KLEMS spreadsheet these series are codes F,G, and 70. The manufacturing series is code D.

We draw two general conclusions from Figure 7. First, as a rule productivity growth in the non-manufacturing sectors is lower than in manufacturing. Second, during the second half of our sample from (1991 through 2002) productivity growth slowed in both manufacturing and non-manufacturing. The change is especially clear for recoveries (periods between a trough and the next peak) when the need for vigorous creation is depressed by the congestion caused by zombies: Productivity growth during the recoveries in the 1990s is much weaker than in the 1980s.

More importantly for the zombie hypothesis is that the relative behavior of manufacturing and non-manufacturing also has shifted during the 1990s. From the end of the deep 1982 recession until the onset of the recession in 1991, manufacturing and non-manufacturing productivity growth differed by 1.5 percent per year. The relative gap widened substantially through the 1990s; for instance, during just the recovery periods of 1993-97 and 1999-2000, the gap was over 3.8 percentage points per year. This gap pattern is consistent with the prevalence of zombies during the 1990s.

5. Firm-level zombie distortions

We read the evidence in the last section as showing that zombies are distorting industry patterns of job creation and destruction, as well as productivity in the ways suggested by the model. To test directly the model's predictions, we next look at firm-level data to see if the rising presence of zombies in the late 1990s had discernible effects on healthy firms (which would suffer from the congestion created by the zombies).

The data we analyze are from the Nikkei Needs Financial dataset and are derived from income statements and balance sheets for firms listed on the first and second sections of the Tokyo Stock Exchange. The sample runs from 1981 to 2002, and it contains between 1,844 and 2,506 firms depending on the year. We concentrate on three variables: employment growth (measured by the number of full-time employees), the investment rate (defined as the ratio of investment in depreciable assets to beginning of year depreciable assets measured at book value), and a crude productivity proxy (computed as the log of sales minus 1/3 the log of capital minus 2/3 the log of

employment).[23]   In all the regressions reported below we dropped observations in the top and bottom 2.5% of the distribution of the dependent variable.

The simplest regression that we study is:

$$\text{Activity}_{ijt} = \ \delta_1' D_t + \delta_2' D_j + \beta \text{nonz}_{ijt} + \chi Z_{jt} + \varphi \text{nonz}_{ijt} * Z_{jt} \ + \ \varepsilon_{ijt} \qquad (26)$$

where activity can be either the investment rate, the percentage change in employment, or our productivity proxy, D_t is a set of annual dummy variables, D_j is a set of industry dummy variables, nonz$_{ijt}$ is the non-zombie dummy (defined to be one minus the zombie indicator), and Z_{jt} is the percentage of industry assets residing in zombie firms.

Because of the reduced form nature of both the regression equation and the modeling of the subsidies to the zombies, we do not attempt to interpret most of the coefficients in these regressions. For instance, we include the year dummies to allow for unspecified aggregate shocks. Likewise, we can imagine that the zombies' subsidies are so large that they wind up investing more (or adding more workers) than the healthy firms; so we do not propose to test the theory by looking at the estimates for β, the coefficient on the non-zombie dummy. The one exception to this general principle is that for the productivity specification the model clearly predicts that non-zombies will have higher average productivity than zombies.

We instead focus on what we see as the novel prediction of the theory: that the rising zombie congestion should harm the non-zombies. The prediction is most clearly shown in (23), which shows the effects when we define each firm as a collection of projects. The cross-derivatives in (23) show that when there are more zombies in the industry, a negative shock leads to a larger increase in destruction, reduction in creation, and reduction in the total number of projects carried out by the non-zombies. This prediction suggests that φ should be negative in the investment and employment regressions, and positive in the productivity specification.

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[23] In the model there is no distinction between capital and labor. As noted by an anonymous referee, if subsidized interest rates bias zombies toward capital-intensive technologies, then congestion could be more severe in the capital market than in the labor market. However, it is also possible that subsidized loans are only meant to finance working capital, in which case the bias goes the other way around. We have no way to distinguish between these possibilities in our data.

The second through fourth columns of Table 3 shows our estimates for equation (26) for the crisp zombie index. We draw two main conclusions from this simple specification. First, as predicted by the theory, increases in percentages of zombie firms operating in an industry significantly reduces both investment and employment growth for the healthy firms in the industry.[24] Second, looking at column 4, the productivity gap between zombies and non-zombies rises significantly as the percentage of zombies in an industry rises. These findings are consistent with the main predictions of our model. Note that for the investment (employment) specification one might normally expect that as the percentage of sick firms in the industry rises, the healthy firms would have more (relative to the sick ones) to gain from investing (expanding employment). Thus, under normal (non-zombie) circumstances there would be good reasons to expect φ to be positive rather than negative.

The main reason, other than ours, for finding a negative φ is if the zombie percentage in the industry (for that year) is somehow standing in for the overall (un)attractiveness of operating in the industry (for that year). To this potential objection to our results we start by noting two things. First, our definition of zombies, by virtue of only using interest rate payments, does not guarantee that growth opportunities are necessarily bad just because the zombie percentage is high. Second, in order to be consistent with our findings, the reaction to industry conditions must be different for zombies and non-zombies. In particular, non-zombies must be more affected by an industry downturn than zombies for φ to come out negative.

Nonetheless, we make several attempts to address this potential problem. Our first alternative is to add industry-year dummies to equation (26), so that we estimate:[25]

$$\text{Activity}_{ijt} = \delta_3' D_{jt} + \beta \text{nonz}_{ijt} + \varphi \text{nonz}_{ijt} * Z_{jt} + w_{ijt} \qquad (27)$$

This specification controls for all the factors that affect all the firms in an industry in a certain year.[26] Note that we cannot identify the coefficient on the industry zombie

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[24] We ran a similar regression using investment rates for US firms covered in the Compustat database between 1995 and 2004. In this regression φ was insignificantly different from zero. The limited information on debt structure in Compustat no doubt introduces noise in zombie assignments and we did explore many alternatives to deal with this. But this result suggests to us that there is not a mechanical reason to find that φ is significantly negative in this type of regression.

[25] We thank two anonymous referees for suggesting this approach.

percentage anymore, but we can still estimate φ, which is the primary coefficient of interest.[27]

Second, we seek to find other controls for business opportunities for the healthy firms. Our main control to address this problem is to add current sales growth of each firm to the regression specification. Thus, our second alternative specification is:

$$\text{Activity}_{ijt} = \delta_3' D_{jt} + \beta \text{nonz}_{ijt} + \varphi \text{nonz}_{ijt} * Z_{jt} + \theta s_{ijt} + v_{ijt} \qquad (28)$$

where s_{ijt} is the growth rate of sales and the other variables are defined as in the previous two equations.[28]

The next three columns in Table 3 show that controlling for the full set of interactions between industry and time dummies leads to modest changes in the estimates; the estimate of φ for the employment growth is now only different from zero at the six percent level of significance. These estimates suggest to us that unobserved time-varying industry-specific shocks are not driving the results.

The final three columns in the table show the results when sales growth is included as additional control. For the investment specification, this type of accelerator specification generally performs quite well in a-theoretic horse-races among competing specifications (see Bernanke, Bohn and Reiss (1988)). We recognize that the inclusion of sales growth in the employment and productivity specifications is questionable, but it shows up as highly significant in those specifications as well (and it is hardly obvious which other balance sheet or income statement variables would be better pretty proxies

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[26] For instance, if industry-specific policies by the government were time-varying this specification would controll for the changes.

[27] We could go further and add firm-fixed effects to control for all the factors that are not included in the regression that are specific to each firm. However, if the zombie status of firms is persistent over time, this approach loses much of the useful information Nonetheless, we estimated regression (27) controlling for firm fixed-effects. Surprisingly, the estimate of φ continues to be negative and significant in the investment and employment regressions. The results for the productivity regression change. The point estimate of φ is now negative but it is not significantly different from zero.

[28] We also allowed the coefficient on sales growth to differ for non-zombies, but the slope was never different, so to save space we only report the estimates that impose the same coefficient for both types of firms.

for potential growth opportunities).[29] Controlling for sales growth raises the adjusted R^2 for all three equations, and further reduces the estimate of φ for the employment specification, so that it is only different from zero at 20 percent level of significance.

In Appendix 2, we report a long list of robustness exercises, including estimating of (26), (27), and (28) using alternative definition of zombies, omitting marginal zombies, as well as using different measures of minimum required interest rates in the construction of zombie indicators. While the level of significance and some of the point estimates vary across these multiple scenarios, the general flavor of the results does not. More specifically, the estimates for φ tend to be negative and consistently significant for the investment regressions, negative and mostly significant for the employment regressions, and positive and consistently significant for the productivity regressions.

In the remainder of our discussion we attempt to quantify the impact of zombie firms on investment and employment growth of non-zombies. We focus on the five non-manufacturing industries, where our asset weighted measures of zombies were particularly high in the late 1990s. For a typical non-zombie firm in each of these industries, we estimate how much more the non-zombie would have invested or increased employment if there had not been so many zombies in the industry. We consider two alternative low zombies scenarios. In "Case 1," we assume that the zombie index stayed at its average value from 1981 through 1992 for each industry and calculate how much more a typical non-zombie firm would have invested (or employed) over the next ten years. In "Case 2," we assume that the zombie index for the industry was the same as that for manufacturing for each year from 1993 to 2002. We calculate the cumulative investment under these two scenarios and compare it to the typical amount of annual investment (defined as the average of the median rates) during this period. For employment, we compare the cumulative decline attributable to the zombies with the typical annual change over the period (again defined as the average of the median rates). In all of these calculations we take the regression estimates based on the crisp zombie

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[29] As an anonymous referee pointed out, it is possible to derive an equation relating employment to past sales as an optimizing choice in which a firm attempts to keep its labor sales ratio close to a desired level in the presence of labor adjustment costs. In this case, employment growth depends on the lagged sales and employment levels. We estimated the regressions of this type with lagged (log of) sales and lagged (log of) the employment as additional variables (with or without sales growth) and found that the estimate of φ is still negative and statistically significant.

indices in Table 2 using the first specification in the table, and ignore any feedback from industry equilibrium considerations.

More specifically, the investment (or employment) is estimated to have been higher than the actual level by $(\hat{\chi} + \hat{\varphi})(actual\ zombie\ index - alternative\ zombie\ index)$. Noting the possibility that the industry zombie index may be proxying for unobservable industry-year specific profitability shock, one can argue that this calculation overestimates the pure impact of zombies by including the estimate of χ. To address this concern, we also report $\hat{\varphi}(actual\ zombie\ index - alternative\ zombie\ index)$, which would be a lower bound for the pure zombie impact. Of course, all these estimates are subject to substantial uncertainty and do not take into consideration general equilibrium effects, but they are still informative and suggestive of the large negative impact of zombies.

Table 4 shows that both investment and employment growth in non-zombie firms would have been higher in all these industries had there been less zombies. In some industries, the difference is quite large. For example, for the typical non-zombie firm in the wholesale industry the cumulative investment loss (compared with the hypothetical case where the zombie index remained to be at its 1981-1992 average) was about 43.2% of capital, which was more than 3.5 years worth of investment during this period. Even the lower bound estimate that includes only the differential effects on non-zombies (calculated from the coefficient estimate on the interaction term) shows the cumulative loss of 17% of capital, which is still more than one year worth of investment.

The effects on employment growth are large as well. For example, the employment growth of a typical non-zombie real estate developer would have been higher by 9.5 percentage points at the end of the period if the zombie percentage had not risen (which can be compared to the average hiring in the industry of 0.62% per year). Even the lower bound estimate shows that employment growth at a typical non-zombie in the real estate industry would have been higher by more than 3 percentage points.

6. Final Remarks

Our mechanism has aspects of conventional credit crunch stories, but it is also distinct. In our model, the essence of a credit crunch acts as a reduced form profit shock. Thus, if a pure contraction in credit availability was all that was going on, the economy

would be expected to behave like the normal benchmark case we analyze, with a rise in destruction and a fall in creation. Instead, the data show that destruction *falls* more in the sectors with more zombies, suggesting there is more than a simple credit crunch story at work.[30]

At the same time, we do not dispute the observation that credit availability was likely to have fluctuated in the wake of the asset price collapse. Accordingly, it is not surprising that studies such as Kitasaka and Ogawa (2000) find evidence of a classic credit crunch.

Rather than positing and trying to test between more complicated versions of the zombie and credit-crunch hypotheses, we think it is more important to recognize that these mechanisms are fundamentally complementary. If there were financial frictions then the zombie congestion would exacerbate them by lowering collateral values (even for healthy firms). Thus, we see the spillover effects of the zombies as being the most important to emphasize.

One key characteristic of our mechanism is that zombies create on-going distortions that lower job creation and industry productivity. A straightforward extension of the model would make long-run productivity growth endogenous. In this case the present value of the costs due to the suppression of restructuring generated by continuing forbearance with the zombies would greatly exceed calculation based only on the direct costs of subsidies.

While our model is not structural enough to provide an analysis of optimal government regulation, or to assess whether the costs in terms of productivity loss were outweighed by the benefits of reduced unemployment, we argue that Japanese regulators may have failed to recognize the large costs of allowing zombies to continue operating during the episode. For example, the capital injections given to Japanese banks in the late 1990s did not recapitalize the banks sufficiently so that they no longer had an

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[30] For example, one may argue that a credit crunch could depress creation particularly if it hits small and young firms. However, these firms are not the typical ones in our sample of publicly traded firms. Moreover, we do not observe the spike in job destruction that would accompany a credit crunch that afflicts small firms disproportionately. Finally, if we assume that smaller firms' main credit source is from banks, then the observation that the distortions are bigger when there are more zombies in the same industry, would require a very special pattern of lending. The banks would have to be financing more small firms in precisely the industries where the zombies became most important. We are unaware of any evidence suggesting that this was the case.

incentive to evergreen. The forgone benefits that would have accrued had Japan returned at that point to having a normally functioning economy could have been large enough to justify a very generous transition policy package to the displaced workers that would have been released if the zombies were shuttered.[31]

Finally, our description of the Japanese experience is similar to the diagnosis that has been used to describe the early phases of the transition of many former socialist economies to become market-oriented. In these economies the depressing effects on the private sector of the continued operation of state-owned enterprises (typically funded by state owned banks) is often noted; discussions of the situation in China in the 2000s would be the latest of these examples. Also, note that the key to our mechanism is lack of restructuring, which also may be caused by legal bankruptcy procedures that protect debtors rather than by banks' behavior. For example, in the U.S. airline industry it is routinely asserted that the industry has been plagued because unprofitable carriers go bankrupt, yet they fail to exit the industry (see Wessel and Carey (2005)). These cases suggest that the mechanism that we have sketched is not unique to Japan.[32]

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[31] The same reasoning applies to the question of whether the lack of liquidations in the U.S. airline industry raised or lowered the taxpayers' costs of rationalizing the industry.

[32] See Caballero (2007) for a discussion of different models and manifestations of sclerosis in macroeconomics.

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Appendix 1

The variable R^* plays a critical role in our analysis. In this appendix we provide some additional details on the construction of this variable and the other data used in the analysis.

In constructing R^* our goal is to produce a plausible lower bound for what firms might pay to borrow. For the portion of the interest payments coming from short term bank loans, which accounts for about 40% to 45% of total lending in our sample, we believe that this is straightforward because almost no loans are made at rates below the prime rate (once we take into account all the origination and other fees). Thus, we view the use of the short term prime rate as relatively uncontroversial.[33]

Ideally, we would find an equally conservative assumption for handling long-term loans. It is quite likely that interest payment on a new long-term loan would be above the prime rate at the time the loan is originated. Unfortunately, the available data on long-term bank debt gives just the stock outstanding without information on the exact maturity of the loans. Thus, we assume that each firm's long term loans have an average maturity of 2.5 years and with one-fifth of them having been originated in each year for five years. Five years corresponds to the average maturity of bank loans at the time of origination in the dataset of Smith (2003). This assumption implies that the right interest rate is an equally weighted average of the last five years of the long-term prime rates. Thus, we calculate the minimum required interest payment on the long-term loans by multiplying the outstanding long-term loans of all maturities with the five year average of the long-term prime rates.

Turning to the non-bank financing, we know that during the 1990s, roughly 40% of interest paying debt was bonds and about 3% was commercial paper. Our measure of the required payment ignores the interest payments for commercial paper. Given the limited importance of commercial paper financing and the low interest rates on the commercial paper for the 1990s, this is not likely to cause any serious problems for our analysis.

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[33] As alternative we instead computed a required rate that imposed a mark up over the London Interbank Borrowing (LIBOR) rate based on the average spreads reported in Smith (2003). This approach produced similar results regarding the numbers of firms with negative interest rate gaps.

For the remaining debt we assume that it was financed as advantageously as possible. Specifically, we assume that bond financing is done with CBs (which by their nature have lower yields) and that firms were always able to time the issues so that the rate is the lowest within the last five years. Implicitly, this presumes that the firms have perfect foresight and refinance their bonds every time there is a local trough in interest rates. This assumption is almost surely understating the required payments on corporate debt. For instance, from 1996 onwards this imputation procedure assumes that all bond financing is done at a zero interest rate. By assuming very low required interest rates on bonds, the approach reduces the risk of our misclassifying credit worthy companies that enjoy extreme low bond rates in the public market as zombies. On the other hand, the approach increases the risk of failing to identify the zombies that pay interests on the bonds they issued in the past. Thus, we can be confident that any firms that we label as zombies must be getting very favorable interest rates from their banks. Put differently, by assuming access to such low bond financing rates our classification scheme picks out only the most egregious zombies that receive massive help from their banks.

Besides this baseline procedure we also explored several approaches. One alternative centered on estimating the maturity structure of each firm each year. Here we just describe the calculation for long-term bank borrowing. We estimate the maturity structure of bonds in the same way.

We observe the total long-term bank borrowing for firm i at the end of accounting year t (BL_{it}) and the long-term bank borrowing that comes due within 1 year ($BL1_{it}$). Let NBL_{it} be the amount of new long-term bank loans that the firm i takes in during year t. We use the following equation to estimate NBL_{it} :

$$NBL_{it} = \max \left\{ BL_{it} - BL_{it-1} + BL1_{it-1}, 0 \right\}$$

Let $BP(n)_{it}$ denote the amount of long-term bank loans to firm *i* that was given in year *t-n* and still outstanding at the end of *t*. We assume the maximum maturity of long-term bank loans to be 10 years. If *NBL* is available for all years in the past 10 years, we can estimate *BP(n)* recursively as follows.

$$BP(0)_{it-1} = \min\left\{NBL_{it-1}, \max\left\{BL_{it-1}, 0\right\}\right\}$$

$$BP(n)_{it-1} = \min\left\{NBL_{it-n-1}, \max\left\{BL_{it-1} - \sum_{k=0}^{n-1} BP(k)_{it-1}, 0\right\}\right\} \quad (n = 1, 2, \cdots, 8)$$

$$BP(9)_{it-1} = \max\left\{BL_{it-1} - \sum_{k=0}^{8} BP(k)_{it-1}, 0\right\}$$

If NBL_{it-n-1} is not available for $n \geq n^*$, we stop the iteration at $n = n^*$ and assume that the remaining borrowings (if any) are uniformly distributed across different maturities. Formally, this implies:

$$BP(0)_{it-1} = \min\left\{NBL_{it-1}, \max\left\{BL_{it-1}, 0\right\}\right\}$$

$$BP(n)_{it-1} = \min\left\{NBL_{it-n-1}, \max\left\{BL_{it-1} - \sum_{k=0}^{n-1} BP(k)_{it-1}, 0\right\}\right\} \quad (n < n^*)$$

$$BP(n)_{it-1} = \max\left\{\frac{BL_{it-1} - \sum_{k=0}^{n^*-1} BP(k)_{it-1}}{10 - n^*}, 0\right\} \quad (n \geq n^*)$$

The associated regression results are shown in Table A-4 (that we discuss in Appendix 2).

For bonds, we also adopted an extremely conservative approach that assumes the minimum required interest rate for bonds was zero for the entire sample period. This approach guarantees that any firms with a negative interest rate gap must be receiving unusually low interest rates on their bank borrowing. The regressions associated with this classification scheme are shown in Table A-5 (and are almost identical to those shown in Table 2).

The data for prime bank loan rates are taken from the Bank of Japan web site (http://www.boj.or.jp/en/stat/stat_f.htm). The subscribers' yields for convertible bonds are collected from various issues of *Kin'yu Nenpo* (Annual Report on Finance) published by the Ministry of Finance.

The remaining data we use for the regression analyses are taken from the Nikkei Needs Corporate Financial Database. The data are annual, so for instance when we refer to 1993 data they are from a firm's balance sheet and income statement for the accounting year that ended between January and December of 1993. The basic properties for sample as of 1993 are shown in Table A-6.

Roughly 2/3 of the sample assets are in manufacturing firms. Among manufacturing industries the coverage of the sample is consistent and fairly high. This is formalized in columns 4 and 5 that compare assets (and sales) for the different industries to their economy-wide counterparts (that are computed from the Ministry of Finance's Statistical Survey of Incorporated Businesses (Hōjin Kigyō Tōkei Chōsa)). The comparison is not exact because the industry classification system used by the MOF Survey differs from the one used in the Nikkei Database. Among the industries in Table A-6, the MOF Survey does not separately identify medical products, rubber products, shipbuilding, and other transportation equipment (i.e. the portion excluding ships and motor vehicles).

The industry composition for manufacturing firms in our sample is also relatively stable over time. For instance, in terms of the percentage of sample assets in the various industries there are virtually no changes between 1993 and 2001; the only cases where the shares differed by more than one percentage point were electric machinery (which gained about 1.75 percentage points and steel which lost about 1.3 percentage points). Between 1981 and 1993 many of the heavy industries (e.g. chemicals, petroleum and coal, non-ferrous metal products, non-electrical machinery, and shipbuilding) shrank and electrical machinery gained over three percentage points.

The coverage is less complete for non-manufacturing firms (see again columns 4 and 5). In the real estate and services industries, our sample firms covered only 8% and 6% respectively of the whole industry in 1993, reflecting the many (unlisted) firms in those industries that are excluded from our analysis.

As of 1981, the percentage of the sample assets in these firms stood at roughly 25 percent, and that climbed to about 1/3 by 1993, with all industries except wholesaling gaining at least one percentage point. From 1993 to 2001, construction firms percentage of sample assets shrank by 3.5 percentage points and retail and service firm picked up most of the share.

Appendix 2

We checked the robustness of the significance of the estimated φ's to several alternative measures of the required minimum interest rate r^* and zombie indices. Table A-1 repeats the regressions from Table 3, using the fuzzy zombie indices with $(d_1, d_2) = (0, 50\text{bp})$ and $(d_1, d_2) = (-25\text{bp}, 75\text{bp})$. We draw three conclusions from this table. First, the estimates of φ are smaller than those in Table 3. However, part of the difference can be explained by the fact that the industry zombie percentages are larger when we use the fuzzy zombie measures than when we use the crisp measures. Second, and probably related, for the estimates of (26), the statistical significance of the estimates of φ is similar to those reported in Table 3; in other words, the declines in the size of the coefficients are accompanied by smaller standard errors, so that the t-statistics are similar.

Adding sales growth to these regressions lowers the statistical significance of the estimates of φ. The estimated signs remain negative for employment and investment and positive for productivity but the coefficient for employment growth is no longer significant.

We also estimated the regressions dropping the observations with x_{it} between d_1 and d_2 entirely. Table A-2 shows the results. The estimates of φ in the investment and employment growth equations are again negative and statistically significant in almost all the cases. Indeed, the coefficients are often larger when we drop the observations with x_{it} close to zero. For the productivity proxy, however, the estimated gap between the zombies and non-zombies (β in equation (26)) rises substantially, while the estimated value of φ falls and becomes insignificant.

We also re-estimated equation (26) and (27) for different zombie definitions shown in Table 2. The first panel in Table A-3 summarizes these results by reporting the estimates of φ in equation (26), and the second panel shows the equation (27) estimates. As a benchmark, the first row of estimates in each panel repeats the results from Tables 3 and A-1 for the baseline crisp and fuzzy definitions. Because the different zombie definitions change the estimated levels of zombies, we do not expect the point estimates for these interaction terms to be the same across specifications; the more conservative definitions would likely yield higher coefficients than the more liberal definitions.

Accordingly, we focus more on the statistical significance of the results, rather than the magnitudes of the estimates.

The most striking pattern in the table is in the last two rows of each panel. These alternatives use more liberal definitions of which firms should be considered as zombies. For employment and productivity, especially for the fuzzy definitions, the significance of the estimates rises substantially. This suggests to us that the baseline definitions are too restrictive and may miss many zombies.

The other noticeable pattern is that automatically excluding firms with BBB rated bonds leads to higher estimated standard errors. With this definition the estimated significance of φ is lower in almost all cases. For these specifications the estimates for employment are typically not significant for either the crisp or fuzzy definitions. The definitions that exclude the firms with A rated bonds are somewhat similar, but the differences with the baseline specifications are much less pronounced.

A third observation is that the significance levels using the full set of industry-time dummies (equation (27) estimates) are typically lower than for baseline equation (26) estimates. The difference is most clearly seen for the employment regressions, but the same pattern seems to hold for the productivity and investment specifications.

Beyond these observations, we see no obvious patterns. For some definitions, the significance rises, but in others it drops.

Table A-4 shows the results using more detailed estimation of the maturity structure for long-term borrowings and bonds discussed in Appendix 1. The coefficient estimates of φ are similar (in size and statistical significance) to those in Table 3 in all the specifications.

Finally, Table A-5 shows the regressions under alternative assumption that the minimum required interest rate on bonds is zero. The results are again similar to those in Table 3, although for the employment specification with full interactions of time and year dummies, the estimate of φ is insignificant.

All in all, the results of these robustness exercises confirm the same broad patterns as in Table 3. The precision of some of our estimates suffer as we modify the measures of zombies to address different measurement and classification errors. However,

the statistical significance of the estimates of φ for the investment and the productivity specifications is especially robust.

Table 1
Search Results For News Articles Regarding Restructured Companies

Total Hits for January 1990 through May 2004	1,196
Of which, related to private sector companies in Japan	1,085
Clear description of the content of "financial assistance" (excludes duplicate articles on the same case)	120
• New loans	19
• Interest concessions（金利減免）	**36**
• Purchase of new shares（新株引き受け）	29
• Debt-Equity swaps	**26**
• Debt forgiveness （債権放棄）	**44**
• Moratorium on loan principle（元本支払猶予）	**11**
• Moratorium on interest payments（利子支払猶予）	**5**

Notes: Search words: "Financial assistance" AND ("Management Reconstruction Plan" OR ("Corporation" and "Reconstruction")); actual phrases were 金融支援 AND (経営再建計画 OR (企業 AND 再建)).

Source: Nikkei Telecom 21.

Table 2
Correlation between Crisp Asset-weighted Zombie Percentage and the Alternatives

	All firms	2002 Zombie%	Manufac-turing	Construc-tion	Real Estate	Trade	Services
Z01	1.0000	14.96%	1.0000	1.0000	1.0000	1.0000	1.0000
Z02	0.9900	21.40%	0.9787	0.9580	0.8648	0.9839	0.9784
Z03	0.9910	22.42%	0.9768	0.9529	0.8554	0.9860	0.9816
ZA01	0.9985	13.34%	0.9953	0.9785	0.9997	0.9977	0.9807
ZA02	0.9867	10.65%	0.9807	0.9430	0.9975	0.9892	0.9673
ZA03	0.9810	14.13%	0.9734	0.9675	0.9204	0.9774	0.9508
ZA04	0.9607	14.14%	0.9456	0.9474	0.8067	0.9548	0.8532
ZA05	0.9851	19.79%	0.9645	0.9179	0.8575	0.9756	0.9576
ZA06	0.9748	17.09%	0.9445	0.8674	0.8620	0.9658	0.9566
ZA07	0.9743	20.62%	0.9583	0.9387	0.8639	0.9726	0.9275
ZA08	0.9467	20.50%	0.9225	0.9193	0.7770	0.9575	0.8255
ZA09	0.9875	22.17%	0.9636	0.9548	0.8532	0.9823	0.9683
ZA10	0.9855	20.70%	0.9595	0.9550	0.8529	0.9793	0.9643
ZA11	0.9725	21.08%	0.9516	0.9372	0.8442	0.9746	0.9303
ZA12	0.9434	21.01%	0.9150	0.9161	0.7438	0.9592	0.8300
ZA13	0.9796	17.42%	0.9764	0.9752	0.8740	0.9742	0.9454
ZA14	0.9692	19.72%	0.9602	0.9691	0.7853	0.9613	0.8723
ZA15	0.9707	24.68%	0.9522	0.9358	0.7881	0.9659	0.9058
ZA16	0.9485	27.62%	0.9142	0.9210	0.7481	0.9584	0.8041
ZA17	0.9676	25.16%	0.9463	0.9416	0.7508	0.9706	0.9163
ZA18	0.9429	28.21%	0.9097	0.9291	0.6640	0.9625	0.8321

Note: The first column shows the (alternative) zombie definition. The column "2002 Zombie%" reports the 2002 (asset weighted) zombie percentage for all firms calculated using the various definitions. The other columns show the correlation coefficient between the zombie indicator calculated using the various definitions and the baseline crisp zombie indicator (Z01) for the sample of firms indicated in the header row.

(Alternative) Definitions:

Z01   Baseline crisp zombie definition (d1, d2) = (0,0)
Z02   Baseline fuzzy zombie with (d1, d2) = (0, 0.005)
Z03   Baseline fuzzy zombie with (d1, d2) = (-0.0025, 0.0075)
ZA01   Crisp zombie excluding firms with bonds rated A or above
ZA02   Crisp zombie excluding firms with bonds rated BBB or above
ZA03   Crisp zombie 2-year average of years t and t-1
ZA04   Crisp zombie 3-year average of years t, t-1 and t-2
ZA05   Fuzzy zombie with (d1, d2) = (0, 0.005) excluding firms with bonds rated A or above
ZA06   Fuzzy zombie with (d1, d2) = (0, 0.005) excluding firms with bonds rated BBB or above
ZA07   Fuzzy zombie 2-year average of years t and t-1 with (d1, d2) = (0, 0.005)
ZA08   Fuzzy zombie 3-year average of years t, t-1 and t-2 with (d1, d2) = (0, 0.005)
ZA09   Fuzzy zombie with (d1, d2) = (-0.0025, 0.0075) excluding firms with bonds rated A or above
ZA10   Fuzzy zombie with (d1, d2) = (-0.0025, 0.0075) excluding firms with bonds rated BBB or above
ZA11   Fuzzy zombie 2-year average of years t and t-1 with (d1, d2) = (-0.0025, 0.0075)
ZA12   Fuzzy zombie 3-year average of years t, t-1 and t-2 with (d1, d2) = (-0.0025, 0.0075)
ZA13   Crisp zombie 2-year maximum of years t and t-1
ZA14   Crisp zombie 3-year maximum of years t, t-1 and t-2
ZA15   Fuzzy zombie 2-year maximum of years t and t-1 with (d1, d2) = (0, 0.005)
ZA16   Fuzzy zombie 3-year maximum of years t, t-1 and t-2 with (d1, d2) = (0, 0.005)
ZA17   Fuzzy zombie 2-year maximum of years t and t-1 with (d1, d2) = (-0.0025, 0.0075)
ZA18   Fuzzy zombie 3-year maximum of years t, t-1 and t-2 with (d1, d2) = (-0.0025, 0.0075)

Table 3
Impact of Zombie Firms on the Investment, Employment and Productivity of Non-Zombies
Using Baseline Zombie Estimates

Dependent Variable	I/K	ΔLog E	Log Sales − ⅔ Log E − ⅓ Log K	I/K	ΔLog E	Log Sales − ⅔ Log E − ⅓ Log K	I/K	ΔLog E	Log Sales − ⅔ Log E − ⅓ Log K
Non-Zombie Dummy	0.0256 (0.0056)	0.00109 (0.001751)	0.0139 (0.0135)	0.0248 (0.0057)	0.0002 (0.0018)	0.0119 (0.0137)	0.0238 (0.0056)	0.0001 (0.0017)	0.0150 (0.0136)
Industry Zombie %	-0.1370 (0.0376)	-0.0454 (0.0116)	-0.3418 (0.0922)						
Non-Zombie * Industry Zombie%	-0.0885 (0.0330)	-0.0232 (0.0102)	0.2183 (0.0756)	-0.0852 (0.0333)	-0.0188 (0.0102)	0.2315 (0.0767)	-0.0716 (0.0321)	-0.0131 (0.0098)	0.1943 (0.0077)
Sales growth							0.3490 (0.0176)	0.1404 (0.0073)	0.3123 (0.0256)
Industry dummies included?	Yes	Yes	Yes	No	No	No	No	No	No
Year dummies included?	Yes	Yes	Yes	No	No	No	No	No	No
Industry*year dummies included?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	22,396	22,429	23,090	22,396	22,429	23,090	22,394	22,428	22,847
$\bar{R}^2$	0.0537	0.0895	0.3599	0.0617	0.1007	0.3590	0.1125	0.1794	0.3705

The sample consists of between 1,844 and 2,506 publicly traded firms (depending on the year). Each regression is estimated after trimming the top and bottom 2.5% of observations (based on the dependent variable). White (1980) standard errors are reported in parentheses under each coefficient estimate. Point estimates for the various dummies variables are omitted from the table. Any firm with actual interest payments below the hypothetical minimum is considered a zombie and any firm where this is not true is a non-zombie ($d_1=d_2=0$ in equation (1)). Two digit industry classifications are used throughout. The industry percentages for zombies are based on the share of total industry assets residing in zombie firms. I/K is the ratio of investment in depreciable assets to beginning of period stock of depreciable assets (measured at book value). E is the total number of full time employees. K is the book value of depreciable assets and sales growth is the log difference of each firm's sales.

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Table 4
Cumulative Impact of Zombie Firms on Non-Zombies

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A. Cumulative investment losses (1993-2002) of the median non-zombie firm in the high zombies industries

Industry	Wholesale	Retail	Construction	Real Estate	Services
Actual Average I/K: 1993-2002	0.1184	0.1871	0.1373	0.0920	0.2215
Cumulative Lost I/K Case 1	0.4323	0.1883	0.2988	0.2842	0.3020
(lower bound)	(0.1697)	(0.0739)	(0.1173)	(0.1115)	(0.1185)
Cumulative Lost I/K Case 2	0.3454	0.1432	0.1804	0.4006	0.5048
(lower bound)	(0.1355)	(0.0562)	(0.0708)	(0.1572)	(0.1981)

"Actual Average I/K: 1993-2002" shows the actual average investment rate (I/K) of the median non-zombie firm in the industry for 1993-2002. "Cumulative Lost I/K Case 1" shows the total amount of investment (I/K) of the typical non-zombie that was depressed during the period compared with the hypothetical case where the asset weighted zombie index had stayed at its average level for 1981-1992. "Cumulative Lost I/K Case 2" shows the total amount of investment (I/K) of the typical non-zombie that was depressed during the period compared with the hypothetical case where the asset weighted zombie index of the industry was the same as that of manufacturing in each year from 1993 to 2002. The coefficient estimates from the regression in the column 2 of Table 2 were used for the calculation. The numbers in the parentheses show the "lower bounds" of the cumulative losses that include only the differential impacts on the non-zombie (calculated from the coefficient estimate on the interaction term).

B. Cumulative employment change (1993-2002) of the median non-zombie firm in the high zombies industries

Industry	Wholesale	Retail	Construction	Real Estate	Services
Average Actual Employment growth: 1993-2002	-0.0136	0.0015	-0.0043	0.0062	0.0140
Cumulative lost employment -- Case 1	0.1238	0.0598	0.0918	0.0951	0.1086
(lower bound)	(0.0402)	(0.0199)	(0.0302)	(0.0314)	(0.0358)
Cumulative lost employment -- Case 2	0.0977	0.0452	0.0548	0.1363	0.1864
(lower bound)	(0.0320)	(0.0151)	(0.0183)	(0.0445)	(0.0602)

"Average Actual Employment Growth: 1993-2002" shows the actual average annual rate of change in the employment at the median non-zombie in the industry for 1993-2002. "Cumulative lost employment Case 1" shows the total rate of new hiring at the typical non-zombie that was depressed during this period compared with the hypothetical case where the asset weighted zombie index had stayed at its average level for 1981-1992. "Cumulative lost employment Case 2" shows the total rate of new hiring at the typical non-zombie that was depressed during the period compared with the hypothetical case where the asset weighted zombie index of the industry was the same as that of manufacturing in each year from 1993 to 2002. The coefficient estimates from the regression in the column 3 of Table 2 were used for the calculation. The numbers in the parentheses show the "lower bounds" of the cumulative losses that include only the differential impacts on the non-zombie (calculated from the coefficient estimate on the interaction term).

Table A-1
Impact of Zombie Firms on the Investment, Employment and Productivity of Non-Zombies
Using Fuzzy Zombie Indices

Dependent Variable	I/K	ΔLog E	Log Sales – ⅓ Log K - ⅔ Log E	I/K	ΔLog E	Log Sales – ⅓ Log K – ⅔ Log E	I/K	ΔLog E	Log Sales – ⅓ Log K – ⅔ Log E
$\{d_1, d_2\}$ (in basis points) in eq. (1)	{0, 50}	{0, 50}	{0, 50}	{0, 50}	{0, 50}	{0, 50}	{0, 50}	{0, 50}	{0, 50}
Non-Zombie Dummy	0.0304 (0.0061)	0.0026 (0.0019)	0.0343 (0.0144)	0.0295 (0.0061)	0.0015 (0.0019)	0.0322 (0.0146)	0.0276 (0.0056)	0.0009 (0.0018)	0.0334 (0.0145)
Industry Zombie %	-0.2016 (0.0335)	-0.0555 (0.0100)	-0.2504 (0.0797)						
Non-Zombie * Industry Zombie%	-0.0572 (0.0264)	-0.0161 (0.0080)	0.1114 (0.0615)	-0.0553 (0.0266)	-0.0122 (0.0081)	0.1168 (0.0626)	-0.0456 (0.0257)	-.0066 (0.0077)	0.1011 (0.0620)
Sales growth							0.3488 (0.0176)	0.1406 (0.0073)	0.3114 (0.0256)
Industry dummies included?	Yes	Yes	Yes	No	No	No	No	No	No
Year dummies included?	Yes	Yes	Yes	No	No	No	No	No	No
Industry*year dummies included?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	22,396	22,429	22,847	22,396	22,429	22,847	22,394	22,428	22,847
$\overline{R}^2$	0.0556	0.0897	0.3631	0.0624	0.1003	0.3620	0.1133	0.1791	0.3709

Table A-1 continued

Dependent Variable	I/K	ΔLog E	Log Sales – ⅓ Log K - ⅔ Log E	I/K	ΔLog E	Log Sales – ⅓ Log K – ⅔ Log E	I/K	ΔLog E	Log Sales – ⅓ Log K – ⅔ Log E
$\{d_1, d_2\}$ (in basis points) in eq. (1)	{-25,-75}	{-25,-75}	{-25,-75}	{-25,-75}	{-25,-75}	{-25,-75}	{-25,-75}	{-25,-75}	{-25,-75}
Non-Zombie Dummy	0.0323 (0.0068)	0.0029 (0.0021)	0.0284 (0.0162)	0.0319 (0.0069)	0.0017 (0.0021)	0.0264 (0.0164)	0.0298 (0.0067)	0.0011 (0.0020)	0.0280 (0.0163)
Industry Zombie %	-0.2295 (0.0368)	-0.0616 (0.0111)	-0.3044 (0.0875)						
Non-Zombie * Industry Zombie%	-0.0583 (0.0294)	-0.0177 (0.0090)	0.1584 (0.0684)	-0.0582 (0.0296)	-0.0137 (0.0090)	0.1637 (0.0698)	-0.0470 (0.0286)	-0.0078 (0.0087)	0.1456 (0.0694)
Sales growth							0.3489 (0.0176)	0.1406 (0.0119)	0.3112 (0.0256)
Industry dummies included?	Yes	Yes	Yes	No	No	No	No	No	No
Year dummies included?	Yes	Yes	Yes	No	No	No	No	No	No
Industry*year dummies included?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	22,396	22,429	22,847	22,396	22,429	22,847	22,394	22,428	22,847
$\overline{R}^2$	0.0559	0.0898	0.3630	0.0624	0.1003	0.3622	0.1132	0.1791	0.3710

The sample consists of between 1,844 and 2,506 publicly traded firms (depending on the year). Each regression is estimated after trimming the top and bottom 2.5% of observations (based on the dependent variable). White (1980) standard errors are reported in parentheses under each coefficient estimate. Point estimates for dummies are omitted. The zombie probabilities are calculated as described in the text using equation (1). Two digit industry classifications are used throughout. The industry percentages for zombies are based on the share of total industry assets residing in zombie firms. Sales growth is the log difference of each firm's sales. I/K is the ratio of investment in depreciable assets to beginning of period stock of depreciable assets (measured at book value). E is the total number of full time employees. K is the book value of depreciable assets. Sample period is 1993 to 2002.

Table A-2
Impact of Zombie Firms on the Investment, Employment and Productivity of Non-Zombies
Excluding observations with the interest rate gap close to zero

Dependent Variable	I/K		ΔLog E		Log Sales − ⅔ Log E − ⅓ Log K		I/K		ΔLog E		Log Sales − ⅔ Log E − ⅓ Log K	
Range of excluded obs (in basis points)	{0, 50}	{-25, -75}	{0, 50}	{-25, -75}	{0, 50}	{-25, -75}	{0, 50}	{-25, 75}	{0, 50}	{-25, -75}	{0, 50}	{-25, -75}
Non-Zombie Dummy	0.0293 (0.0059)	0.0251 (0.0070)	0.0019 (0.0018)	0.0018 (0.0021)	0.0613 (0.0143)	0.0468 (0.0164)	0.0271 (0.0060)	0.0225 (0.0070)	0.0006 (0.0018)	0.0007 (0.0022)	0.0601 (00145)	0.0451 (0.0168)
Industry Zombie %	-0.0972 (0.0390)	-0.1111 (0.0469)	-0.0318 (0.0124)	-0.0262 (0.0145)	-0.2056 (0.0989)	-0.3388 (0.1121)						
Non-Zombie * Industry Zombie%	-0.1274 (0.0356)	-0.1087 (0.0415)	-0.0374 (0.0110)	-0.0383 (0.0127)	-0.0615 (0.0828)	0.0432 (0.0934)	-0.1187 (0.0361)	-0.0950 (0.0420)	-0.0303 (0.0111)	-0.0318 (0.0128)	-0.0546 (0.0848)	0.0550 (0.0964)
Industry dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Year dummies included?	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Industry*year dummies included?	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	17,407	14,161	17,389	14,138	17,697	14,384	17,407	14,161	17,389	14,138	17,697	14,384
$\overline{R}^2$	0.0556	0.0457	0.0897	0.0792	0.3652	0.3595	0.0595	0.0568	0.0981	0.0898	0.3643	0.3580

The sample consists of between 1,844 and 2,506 publicly traded firms (depending on the year). Each regression is estimated after trimming the top and bottom 2.5% of observations (based on the dependent variable). White (1980) standard errors are reported in parentheses under each coefficient estimate. Industry and year dummies are also included in each regression. Any firm with actual interest payments below the hypothetical minimum is considered a zombie and any firm where this is not true is a non-zombie ($d_1=d_2=0$ in equation (1)). Two digit industry classifications are used throughout. The industry percentages for zombies are based on the share of total industry assets residing in zombie firms. Sales growth is the log difference of each firm's sales. I/K is the ratio of investment in depreciable assets to beginning of period stock of depreciable assets (measured at book value). E is the total number of full time employees. K is the book value of depreciable assets. Sample period is 1993 to 2002.

Table A-3
Impact of Zombie Firms on the Investment, Employment and Productivity of Non-Zombies
for Alternative Zombie Definitions from Table 2

{d_1, d_2} (in basis points) in eq. (1)	Reported Estimates and standard errors on Non-Zombie*Industry Zombie % as estimated from equation (26)								
	I/K			ΔLog E			Log Sales – ⅔ Log E – ⅓ Log K		
	{0, 0}	{0, 50}	{-25, 75}	{0, 0}	{0, 50}	{-25, 75}	{0, 0}	{0, 50}	{-25, 75}
Baseline from Tables 3 and A1	-0.0885 (0.0330)	-0.0572 (0.0264)	-0.0583 (0.0294)	-0.0232 (0.0102)	-0.0161 (0.0080)	-0.0177 (0.0090)	0.2183 (0.0756)	0.1114 (0.0615)	0.1584 (0.0684)
Exclude firms with A or above bonds (ZA01, ZA05, ZA09)	-0.0993 (0.0382)	-0.0601 (0.0293)	-0.0532 (0.0310)	-0.0219 (0.0117)	-0.0196 (0.0090)	-0.0151 (0.0095)	0.1979 (0.0871)	0.0214 (0.0697)	0.1251 (0.0726)
Exclude firms with BBB or above bonds (ZA02, ZA06, ZA10)	-0.0964 (0.0397)	-0.0613 (0.0310)	-0.0517 (0.0319)	-0.0161 (0.0122)	-0.0200 (0.0095)	-0.0136 (0.0098)	0.1676 (0.0902)	0.0211 (0.0734)	0.1279 (0.0747)
Two Year Average (ZA03, ZA07, ZA11)	-0.0827 (0.0379)	-0.0553 (0.0290)	-0.0546 (0.0320)	-0.0322 (0.0118)	-0.0210 (0.0090)	-0.0236 (0.0099)	0.3331 (0.0881)	0.1887 (0.0692)	0.2383 (0.0763)
Three Year Average (ZA04, ZA08, ZA12)	-0.0878 (0.0421)	-0.0720 (0.0320)	-0.0695 (0.0349)	-0.0443 (0.0131)	-0.0296 (0.0098)	-0.0331 (0.0107)	0.4003 (0.0974)	0.2236 (0.0757)	0.2677 (0.0827)
Two Year Max (ZA13, ZA15, ZA17)	-0.0720 (0.0277)	-0.0525 (0.0231)	-0.0603 (0.0258)	-0.0264 (0.0084)	-0.0231 (0.0070)	-0.0225 (0.0078)	0.1968 (0.0627)	0.0552 (0.0550)	0.1776 (0.0597)
Three Year Max (ZA14, ZA16, ZA18)	-0.0574 (0.0251)	-0.0440 (0.0218)	-0.0525 (0.0243)	-0.0307 (0.0075)	-0.0200 (0.0064)	-0.0248 (0.0071)	0.1873 (0.0562)	0.1509 (0.0501)	0.1876 (0.0556)

{d₁, d₂} (in basis points) in eq. (1)	Reported Estimates and standard errors on Non-Zombie*Industry Zombie % as estimated from equation (27)								
	I/K			ΔLog E			Log Sales – ⅔ Log E – ⅓ Log K		
$\{d_1, d_2\}$ (in basis points) in eq. (1)	{0, 0}	{0, 50}	{-25, 75}	{0, 0}	{0, 50}	{-25, 75}	{0, 0}	{0, 50}	{-25, 75}
Baseline from Tables 3 and A1	-0.0852 (0.0333)	-0.0553 (0.0266)	-0.0582 (0.0296)	-0.0188 (0.0102)	-0.0122 (0.0081)	-0.0137 (0.0090)	0.2315 (0.0767)	0.1168 (0.0626)	0.1637 (0.0698)
Exclude firms with A or above bonds (ZA01, ZA05, ZA09)	-0.0927 (0.0385)	-0.0562 (0.0296)	-0.0541 (0.0312)	-0.0179 (0.0117)	-0.0166 (0.0090)	-0.0122 (0.0095)	0.2072 (0.0884)	0.0239 (0.0712)	0.1271 (0.0741)
Exclude firms with BBB or above bonds (ZA02, ZA06, ZA10)	-0.0854 (0.0400)	-0.0527 (0.0312)	-0.0498 (0.0321)	-0.0110 (0.0123)	-0.0157 (0.0096)	-0.0105 (0.0098)	0.1836 (0.0913)	0.0322 (0.0748)	0.1338 (0.0761)
Two Year Average (ZA03, ZA07, ZA11)	-0.0707 (0.0382)	-0.0469 (0.0293)	-0.0462 (0.0323)	-0.0240 (0.0118)	-0.0143 (0.0090)	-0.0163 (0.0100)	0.3437 (0.0896)	0.1935 (0.0706)	0.2442 (0.0780)
Three Year Average (ZA04, ZA08, ZA12)	-0.0674 (0.0425)	-0.0554 (0.0324)	-0.0508 (0.0354)	-0.0334 (0.0131)	-0.0205 (0.0098)	-0.0226 (0.0107)	0.4126 (0.0993)	0.2299 (0.0774)	0.2771 (0.0848)
Two Year Max (ZA13, ZA15, ZA17)	-0.0689 (0.0280)	-0.0503 (0.0234)	-0.0582 (0.0261)	-0.0222 (0.0084)	-0.0197 (0.0070)	-0.0181 (0.0078)	0.2050 (0.0636)	0.0517 (0.0561)	0.1819 (0.0609)
Three Year Max (ZA14, ZA16, ZA18)	-0.0510 (0.0253)	-0.0397 (0.0221)	-0.0480 (0.0247)	-0.0267 (0.0075)	-0.0161 (0.0064)	-0.0199 (0.0072)	0.1986 (0.0569)	0.1556 (0.0510)	0.1949 (0.0568)

Impact of Zombie Firms on the Investment, Employment and Productivity of Non-Zombies
Using Estimated Maturity Structure for Long-term Borrowings and Bonds

Dependent Variable	I/K	ΔLog E	Log Sales – ⅔ Log E – ⅓ Log K	I/K	ΔLog E	Log Sales – ⅔ Log E – ⅓ Log K
Sample	1993-2002	1993-2002	1993-2002	1993-2002	1993-2002	1993-2002
Non-Zombie Dummy	0.0125 (0.0062)	-0.0007 (0.0021)	0.0133 (0.0147)	0.0142 (0.0063)	-0.0008 (0.0148)	0.0142 (0.0148)
Industry Zombie %	-0.0668 (0.0520)	-0.0388 (0.0163)	-0.3601 (0.1190)			
Non-Zombie * Industry Zombie%	-0.0867 (0.0505)	-0.0321 (0.0155)	0.2285 (0.1122)	-0.1028 (0.0512)	-0.0350 (0.0155)	0.2172 (0.1131)
Industry dummies included?	Yes	Yes	Yes	No	No	No
Year dummies included?	Yes	Yes	Yes	No	No	No
Industry*year dummies included?	No	No	No	Yes	Yes	Yes
Number of obs.	22,396	22,429	22,847	22,396	22,429	22,847
$\overline{R}^2$	0.0521	0.0897	0.3614	0.0611	0.1013	0.3608

The sample consists of between 1,844 and 2,506 publicly traded firms (depending on the year). Each regression is estimated after trimming the top and bottom 2.5% of observations (based on the dependent variable). White (1980) standard errors are reported in parentheses under each coefficient estimate. Estimates of the various dummies variables are omitted from the table. Any firm with actual interest payments below the hypothetical minimum is considered a zombie and any firm where this is not true is a non-zombie ($d_1=d_2=0$ in equation (1)); the imputed interest rates for bank borrowing and bonds are modified as described in Appendix A-2. Two digit industry classifications are used throughout. The industry percentages for zombies are based on the share of total industry assets residing in zombie firms. Sales is the reported sales for each firm. I/K is the ratio of investment in depreciable assets to beginning of period stock of depreciable assets (measured at book value). E is the total number of full time employees. K is the book value of depreciable assets.
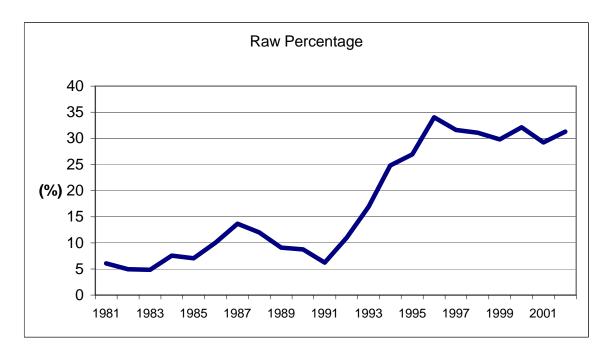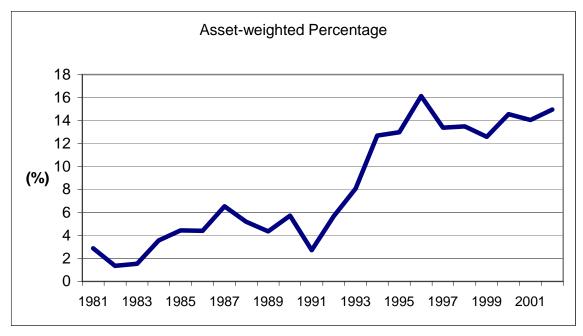
Table A-5
Impact of Zombie Firms on the Investment, Employment and Productivity of Non-Zombies
Assuming Zero for the Minimum Required Interest Rate on Bonds

Dependent Variable	I/K	ΔLog E	Log Sales − ⅔ Log E − ⅓ Log K	I/K	ΔLog E	Log Sales − ⅔ Log E − ⅓ Log K
Sample	1993-2002	1993-2002	1993-2002	1993-2002	1993-2002	1993-2002
Non-Zombie Dummy	0.0237 (0.0056)	0.0007 (0.0017)	0.0129 (0.0133)	0.0220 (0.0056)	-0.0004 (0.0017)	0.0108 (0.0134)
Industry Zombie %	-0.1879 (0.0394)	-0.0533 (0.0123)	-0.3915 (0.0941)			
Non-Zombie * Industry Zombie%	-0.0793 (0.0336)	-0.0213 (0.0104)	0.2283 (0.0764)	-0.0703 (0.0339)	-0.0155 (0.0104)	0.2424 (0.0773)
Industry dummies included?	Yes	Yes	Yes	No	No	No
Year dummies included?	Yes	Yes	Yes	No	No	No
Industry*year dummies included?	No	No	No	Yes	Yes	Yes
Number of obs.	22,396	22,429	23,090	22,396	22,429	23,090
$\overline{R}^2$	0.0521	0.0897	0.3614	0.0616	0.1150	0.3590

The sample consists of between 1,844 and 2,506 publicly traded firms (depending on the year). Each regression is estimated after trimming the top and bottom 2.5% of observations (based on the dependent variable). White (1980) standard errors are reported in parentheses under each coefficient estimate. Estimates of the various dummies variables are omitted from the table. Any firm with actual interest payments below the hypothetical minimum is considered a zombie and any firm where this is not true is a non-zombie ($d_1=d_2=0$ in equation (1)); the imputed interest rates for bonds is assumed to be zero, see the discussion in Appendix A-2. Two digit industry classifications are used throughout. The industry percentages for zombies are based on the share of total industry assets residing in zombie firms. Sales is the reported sales for each firm. I/K is the ratio of investment in depreciable assets to beginning of period stock of depreciable assets (measured at book value). E is the total number of full time employees. K is the book value of depreciable assets.

Table A-6
Sample Summary Statistics for 1993

Industry	# of firms	Share of assets (%)	Share in the overall economy (%)		Total assets (thousand yen)		Depreciable Assets (thousand yen)		Productivity (thousand yen)	
			Assets	Sales	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
All	2360	100.00	23.60%	20.12%	127310	344850	21024	63792	3.2969	0.7249
Food products	125	4.41	40.22%	37.11%	105890	219310	24463	55329	3.3852	0.4564
Textile mill products	76	2.18	64.55%	50.37%	86085	154430	16998	33124	3.0227	0.5949
Paper & allied products	38	1.72	51.17%	37.91%	136270	185260	49558	70452	2.9394	0.3010
Chemicals	181	7.15	52.67%	50.35%	118730	202980	27962	50293	3.0914	0.3106
Medical products	47	2.18	--		139340	163500	19183	21802	2.8858	0.3438
Petroleum & coal products	13	2.39	74.21%	73.58%	553230	626230	81829	77178	4.2080	0.9285
Rubber products	23	0.90	--		117990	228440	24910	35775	2.8311	0.3481
Ceramics	63	1.89	40.11%	32.86%	90001	159570	23248	42273	2.9405	0.4556
Steel	62	5.63	78.85%	70.32%	273040	649320	90894	228310	3.0335	0.3742
Non-ferrous metal products	129	3.80	37.88%	33.45%	88419	145930	18383	35383	3.0635	0.4797
Machinery, non-electric	223	6.31	64.68%	53.61%	85047	263680	13120	33458	2.9104	0.5123
Electric machinery	244	15.47	73.88%	62.00%	190440	561120	28122	81031	3.0086	0.4842
Shipbuilding	7	1.02	--		439600	517490	55032	61206	3.0861	0.1967
Motor vehicles	71	7.34	63.94%	67.96%	310520	869640	69836	156410	3.0407	0.3642
Other transportation equipment	22	0.44	--		60231	56628	12769	16065	2.9909	0.3580
Precision machinery	41	1.19	43.36%	40.10%	86949	129530	13817	20134	2.8800	0.5373
Misc. manufacturing	86	2.13	22.78%	19.05%	74252	148620	14858	36881	3.0892	0.4783
Construction	202	14.16	31.87%	21.34%	210620	438630	9181	20289	3.9441	0.5201
Wholesale	271	7.17	10.52%	7.59%	79455	157200	5388	9858	4.2574	0.9086
Retail	170	5.07	14.66%	13.79%	89601	151780	15395	26231	3.5671	0.4293
Real Estate	53	4.46	8.14%	11.11%	252780	516730	28285	62389	3.5030	0.6612
Services	213	3.00	5.69%	5.98%	42302	72247	7630	13154	2.9103	0.6619

Industry	Investment Rate (I/K)		Sales Growth		Employment Growth		Number of Employees	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
All	0.3284	0.7473	-0.0275	0.1548	0.0344	0.4731	1867.8	4655.4
Food products	0.2664	0.2995	0.0069	0.0682	0.0307	0.1030	1678.70	2911.20
Textile mill products	0.2482	0.4107	-0.1006	0.1138	-0.0154	0.0823	1537.90	2308.70
Paper & allied products	0.1933	0.2383	-0.0515	0.0581	-0.0061	0.0418	1529.30	1663.70
Chemicals	0.2690	0.2476	-0.0348	0.0925	0.0177	0.0942	1493.50	2248.30
Medical products	0.4017	0.5125	0.0570	0.0751	0.0222	0.0541	2264.10	2155.70
Petroleum & coal products	1.1045	2.4836	-0.0314	0.1241	0.0129	0.0704	1662.80	1363.40
Rubber products	0.2766	0.2062	-0.0506	0.0851	0.0038	0.0585	2369.30	3464.40
Ceramics	0.2471	0.2116	-0.0318	0.0843	0.0063	0.0459	1358.90	2073.50
Steel	0.1864	0.1941	-0.1131	0.0756	-0.0065	0.0835	3100.00	6720.70
Non-ferrous metal products	0.3334	0.6129	-0.0420	0.1092	0.0399	0.2082	1498.40	2171.30
Machinery, non-electric	0.3097	1.1883	-0.1172	0.2077	0.0029	0.0644	1462.90	3533.10
Electric machinery	0.2322	0.2128	-0.0720	0.1260	0.0076	0.1712	3724.30	10093.00
Shipbuilding	0.3595	0.2646	0.0075	0.0686	0.0237	0.0114	6402.60	7590.00
Motor vehicles	0.2384	0.1328	-0.0200	0.0631	0.0145	0.0345	6105.90	11750.00
Other transportation equipment	0.2294	0.1707	-0.0718	0.1044	-0.0119	0.0577	1207.70	962.16
Precision machinery	0.3206	0.4658	-0.1135	0.1499	-0.0141	0.0875	1809.10	2121.40
Misc. manufacturing	0.2945	0.4929	0.0044	0.1742	0.0259	0.0866	1470.40	2408.00
Construction	0.3702	0.4170	0.0378	0.0984	0.0429	0.0568	1909.10	2503.20
Wholesale	0.4219	1.2048	-0.0341	0.1163	0.0219	0.1344	888.78	1145.20
Retail	0.3936	0.6091	0.0656	0.2566	0.2276	1.7322	1736.00	2750.20
Real Estate	0.5142	1.4205	0.0094	0.2619	0.0087	0.1182	400.23	501.00
Services	0.4001	0.8900	0.0283	0.1671	0.0563	0.1847	1013.90	1315.30

Figure 1: Prevalence of Firms Receiving Subsidized Loans in Japan

Note: Percentages calculated as described in the text, with $d_1=d_2=0$ in equation 1.
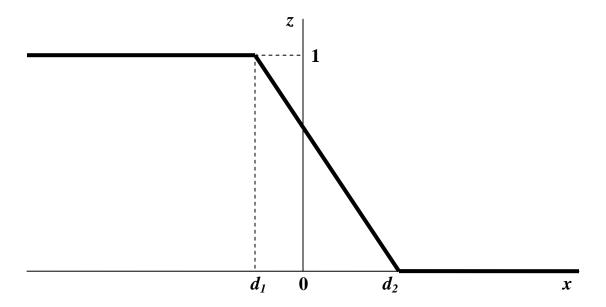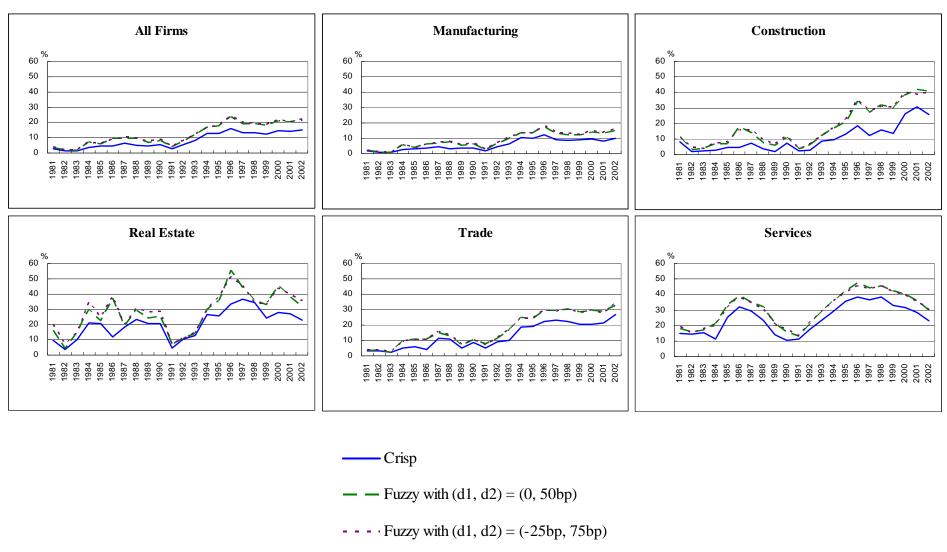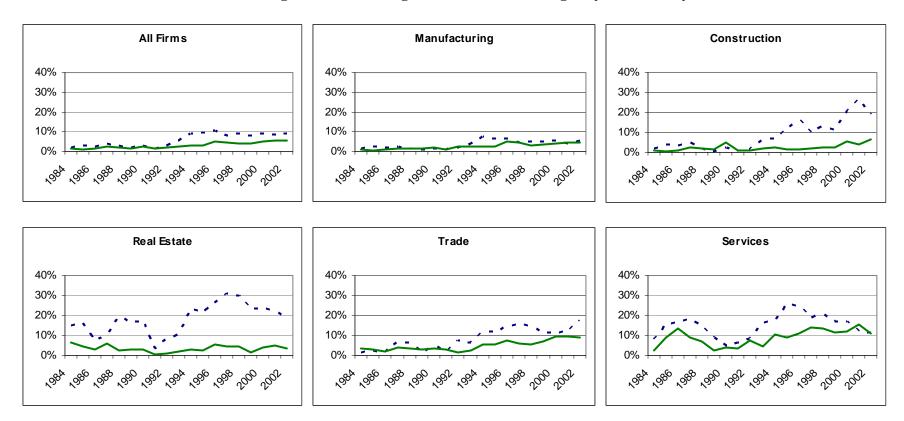
Figure 2: Membership Function for a Fuzzy Zombie Set

Figure 3: Cross-Industry Incidence of Asset Weighted Zombie Percentage for Crisp and Fuzzy Zombie Definitions

Crisp

Fuzzy with (d1, d2) = (0, 50bp)

Fuzzy with (d1, d2) = (-25bp, 75bp)

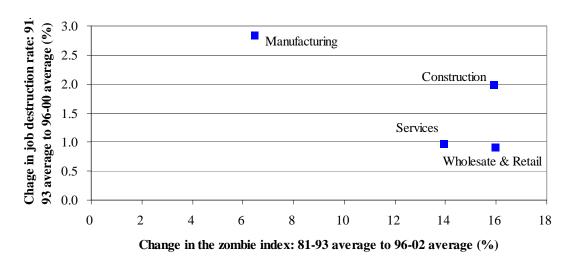Note: Fuzzie zombie definitions computed according to equation 1, see text for details.

Figure 4: Asset Weighted Zombie Percentages by Profitability

Note: Solid lines show zombie percentage for firms whose profits are above the median for the industry, dashed show below median.

Figure 5

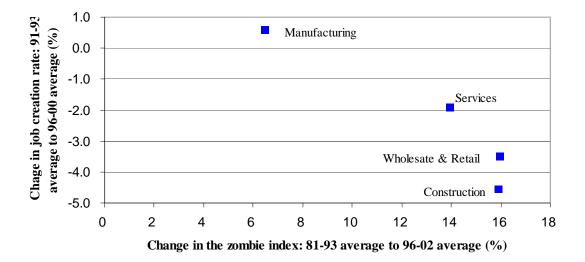**Zombies and Job Destruction**
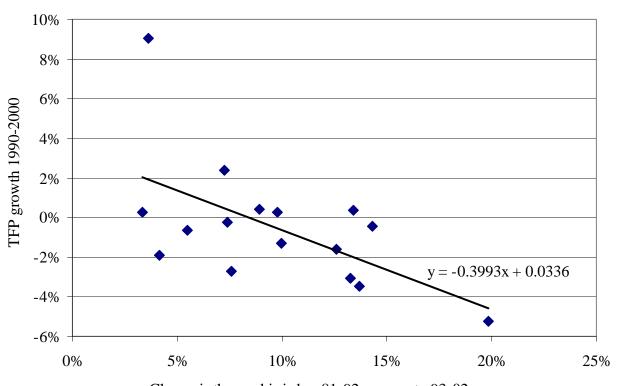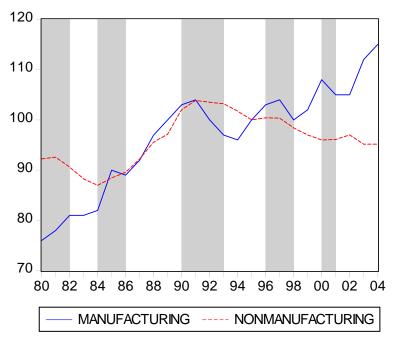

Zombies and Job Creation

Figure 6

Zombies and TFP Growth

Figure 7

Total Factor Productivity by Industry: 1980-2002 (1995=100)

Source: Project on Productivity in the European Union: A Comparative Industry Approach (EU KLEMS2003) (http://www.euklems.net/)