ECONOMIC RESEARCH CENTER
DISCUSSION PAPER

E-Series

No.E14-10

Specificity and Economic Performance

by

Koji Yoneda
Tadashi Minagawa

December 2014

ECONOMIC RESEARCH CENTER
GRADUATE SCHOOL OF ECONOMICS
NAGOYA UNIVERSITY

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Specificity and Economic Performance*

Koji Yoneda† and Tadashi Minagawa‡

Abstract

Long-term business relationships with specific investments prevail extensively in transactions of intermediate goods, while economic theories have traditionally presumed market transactions. But relation-specific production is also known to have a weakness to economic shocks. This paper provides models of specific relations between a manufacturer and its suppliers, examining how the degree of specificity affects the impact of demand shocks on the ways of production, on the value of output, and the like. The main findings we obtained are as follows. (i) Once the market conditions fall below some critical level, specific relations break down rapidly. (ii) Facing a large drop in demand, the percentage decrease in the value of output is greater in an industry with higher specificity than lower specificity. (iii) Specific relations make output more responsive to negative demand shocks.

JEL codes: D23, L14, L62, L64.

Keywords: relationship specificity, vertical relationships, global recession, Japanese manufacturing.

1 Introduction

Long-term business relations with investments in specific assets prevail extensively in actual inter-firm transactions, while economic theories have traditionally presumed market transactions.[1] Especially in transactions of intermediate goods, specific relations are observed prominently (well-developed supply chains are found in many industries). Indeed, it can be said that, except for final goods, few goods are sold and purchased through the

*We are grateful for helpful comments to Sharif Mebed and the participants of the workshop "2011 Mathematical Economics" in Research Institute for Mathematical Sciences, and Kyoto Institute of Economic Research, Kyoto University.

†Economic Research Center, Graduate School of Economics, Nagoya University.

‡Department of Business Administration, Tokaigakuen University. Professor Emeritus of Nagoya University.

[1]For example, Oliver Hart (1995) writes, "Economists have a very well-established theory of market trading and are on the way to possessing a similarly well-developed theory of contractual transactions. The economic analysis of institutions, however, is in a much more rudimentary state."

But we can find insightful discussions on relation-specific investments in the modern economic analysis of institutions, e.g., Benjamin Klein, Robert G. Crawford, and Armen A. Alchian (1978); Oliver E. Williamson (1985); Sanford J. Grossman and Oliver D. Hart (1986); Oliver Hart and John Moore (1990); Daron Acemoglu, Pol Antràs, and Elhanan Helpman (2007); Nisvan Erkal (2007); and Charles I. Jones (2011).

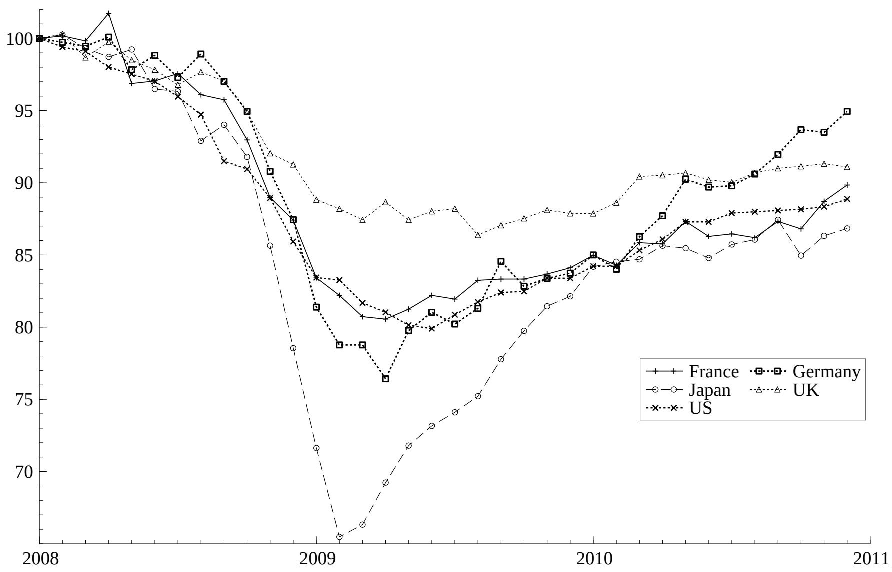

Figure I: Index of Industrial Production Compared by Country.
Source: Ministry of Economy, Trade and Industry (for Japan); Board of Governors of the Federal Reserve System (for US); Eurostat (for France, Germany, and UK).

market. Similarly in transactions between employer and workers, long-term employment for accumulating firm-specific skills is often observed.[2]

Why are specific relations highly developed in the transactions of many intermediate goods? One reason is that production for specific customers enables firms to produce more valuable goods more efficiently than production for general purpose. In this way, it appears that specific transactions generate gains from specialization. However, in some studies, firm-specific production is also known to have a weakness in regards to economic shocks (Olivier Blanchard and Michael Kremer 1997; Ricardo J. Caballero and Mohamad L. Hammour 1998).

It has been argued that specific production is prevalent in Japan, as observed in its automobile (Banri Asanuma 1989; Jeffrey H. Dyer 1994) and electric machinery industry (Toshihiro Nishiguchi 1994). In the global recession that began in the United States in the late 2000s, Japan experienced a larger decline in industrial production than other advanced countries (Figure 1). Above all, the Chubu region,[3] which is a center for machinery manufacturing including automobiles, exhibited poor economic performance (Figure 2). In addition, the industries that had exhibited higher profitability were more likely to have a larger decline in production. Those facts suggest that the weakness of specificity may have played an important role in the large decline in Japanese industrial production.

Japan also had a serious recession in the late 1990s. This recession was triggered by the domestic financial shock known as "the collapse of the asset price bubble." A number of economists have explicated the mechanisms that causes financial shocks to affect real

[2]Gary Becker (1964) is one of the most famous studies that analyzes relation-specific investments in human capital.

[3]Chubu is the central region of the main island of Japan.

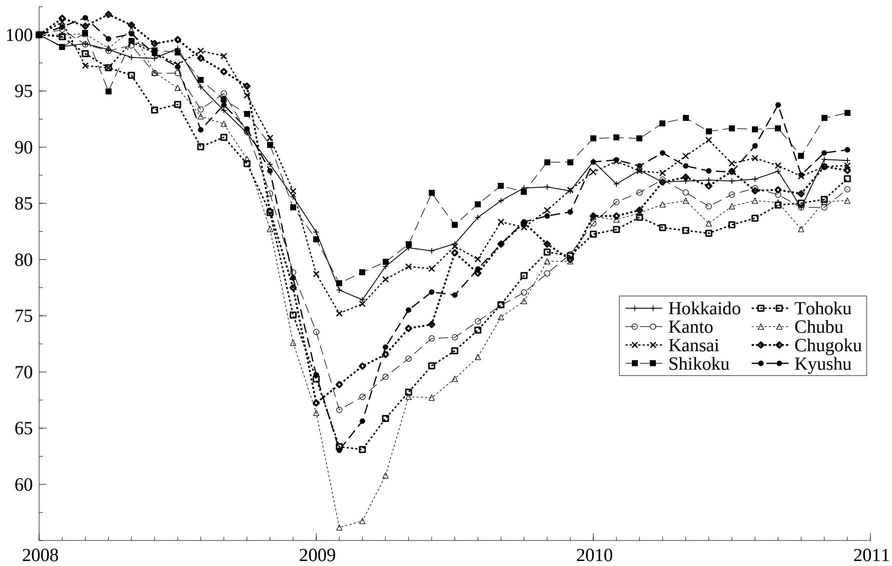

Figure II: Index of Industrial Production Compared by Region in Japan.
Source: Hokkaido Bureau of Economy, Trade and Industry; Tohoku Bureau of Economy, Trade and Industry; Kanto Bureau of Economy, Trade and Industry; Chubu Bureau of Economy, Trade and Industry; Kansai Bureau of Economy, Trade and Industry; Chugoku Bureau of Economy, Trade and Industry; Shikoku Bureau of Economy, Trade and Industry; Kyushu Bureau of Economy, Trade and Industry.Source: Hokkaido Bureau of Economy, Trade and Industry; Tohoku Bureau of Economy, Trade and Industry; Kanto Bureau of Economy, Trade and Industry; Chubu Bureau of Economy, Trade and Industry; Kansai Bureau of Economy, Trade and Industry; Chugoku Bureau of Economy, Trade and Industry; Shikoku Bureau of Economy, Trade and Industry; Kyushu Bureau of Economy, Trade and Industry.

economies (e.g., Nobuhiro Kiyotaki and John Moore 1997; Ricardo J. Caballero, Takeo Hoshi, and Anil K Kashyap 2008). The recession of the late 2000s was also triggered by a financial shock. Nevertheless, it is notable here that the Japanese economy was depressed to a greater extent than the U.S. economy despite the fact that it was the source of the recession. This also implies that higher specificity in Japanese manufacturing may have something to do with the larger decline in its output.

In this paper, focusing on specific relations between a manufacturer (an assembly firm) and its suppliers (as observed in machinery manufacturing), we will show that in a major recession, an industry with higher specificity experiences a larger decline in the value of output. In our model, this arises from the replacement of customized intermediate goods by standardized general-purpose goods. For example, a trend to standardize intermediate goods can be found in the semiconductor market. The total sales of "logic" products, which include customer specific products, decreased 11.3 percent in 2009 compared to the previous year, whereas "MOS memory" products, most of which are standardized, decreased only 3.3 percent.[4]

Our analysis compliments other explanations of the weakness of specificity to economic

[4]The source is World Semiconductor Trade Statistics (WSTS), "News Release June 2010." In the product classification by WSTS, "logic" includes ASIC (Application Specific Integrated Circuits) such as CSIC (Customer Specific Integrated Circuits). "MOS memory" consists of DRAM (Dynamic Random Access Memory) devices, flash memory products, and the like.

shocks. Keiichiro Kobayashi (2000) explains that the delay in disposal of debt overhang, which makes it difficult to commit to specific relations, leads the economy to persistent stagnation. Caballero and Hammour (1998) show that a holdup problem arising from specificity reduces the creation of new relations and thereby makes the cyclical response of the economy elastic in recessions.

In contrast, we will describe that specificity increases the effect of negative demand shocks through the following mechanism. Facing a large demand shock, assembly firms shift from using specific intermediate goods to market-produced ones as a result of their profit maximization. Shifting to market-produced goods reduces the market value of the final good. In consequence, the value of output is reduced not only by the demand shock itself but also by the decreased product value due to the breakdown of specific relations. Hence, where specific relations prevail more extensively, output is more responsive to negative demand shocks.

Our analysis is based, to a large extent, on Blanchard and Kremer (1997). They focus on an aspect of specific relations where firms have no alternative suppliers, showing the weakness of specificity. In the early 1990s, the countries of the former Soviet Union had a large decline in output. According to their analysis, high specificity where state firms had only one supplier for each input played an important role in this large decrease. They provide sophisticated models to explain how specificity, together with either incompleteness of contracts or asymmetric information, causes a large decline in output. Different from Blanchard and Kremer, our model examines how decreased demand affects the production of private firms in market economies, whereas they show how the improvement in private opportunities can lead to the collapse of production in the state sector. In this paper, we do not consider the creation of new relations in recovery periods, because our concern here is with the dissolution of pre-existing relations in recessions.

In Section II, we set up a basic model and draw the following insights: once the market conditions fall below some critical level, specific relations break down rapidly; Facing a large drop in demand, the percentage decrease in the value of output is smaller in an industry with higher specificity than lower; specificity making output more responsive to negative demand shocks.

Our basic model makes the assumption that if one or more inputs cannot be provided by specific suppliers, the market value of the final goods falls to the lowest level. This production technology is assumed in Blanchard and Kremer's model. Blanchard and Kremer interpret this production technology as a kind of Leontief technology since all inputs combine in a Leontief fashion. As an alternative way of modeling specificity of intermediate goods, for example, Jones (2011) uses a CES function. In Section III, weakening the assumption, we consider another model in which the market value of the final goods increases linearly with the fraction of inputs provided by specific suppliers. This second model provides robustness to our findings by showing that specific relations exhibit the same features as obtained in the basic model.

In Section IV, we provide empirical evidence that an industry with higher specificity had a greater output decline in Japan during the late 2000s global recession. Finally, Section V concludes this paper. An appendix follows.

2 Basic Model

2.1 Technology and Intermediate Goods Transactions

The model is as follows. An assembly firm needs n inputs in order to produce n units of a final good. Each input is provided by one supplier. In addition, specific relations between an assembly firm and its suppliers increase the market value of the final good by customizing the intermediate goods. Therefore, if all inputs are customized by specific suppliers, the final goods are sold at the price $(1+\theta)v$. If one or more inputs cannot be customized, the final good price falls to v. The parameter v is given by the market conditions, and $\theta > 0$ by available technologies.

Each input is produced at the cost c, distributed uniformly on $[0, 1]$. Draws are independent across suppliers (i.e., if we let c_i denote c for the i th supplier or the i th input, $\mathrm{Cov}(c_j, c_k) = 0$ for all $j \neq k$). The distribution of c is known, but the specific realization of each c is private information to each supplier (i.e., there is information asymmetry between the assembly firm and each supplier).

The assembly firm maximizes expected profit, and it announces a take-it-or-leave-it price p to each supplier (given the symmetry built in the assumptions, the price is the same for all suppliers). If p exceeds c for all suppliers, specific production takes place in the assembly firm. Otherwise, it cannot take place, because the suppliers with $c > p$ cannot produce the customized goods.

When one or more suppliers cannot produce the customized goods, the final goods are sold at the price of only v, regardless of whether the other inputs are customized. For this reason, when some inputs cannot be customized, the assembly firm decides to purchase all inputs from the market and ends its relations with all suppliers. In other words, the assembly firm shifts from *specific production* to *market production*. In the market for intermediate goods, the assembly firm purchases each input at the price equal to the specific realization of c.

This model is assuming that the assembly firm announces a take-it-or-leave-it price p to its suppliers. This assumption is made in Blanchard and Kremer's model. In Japanese automobile manufacturing, the take-it-or-leave-it assumption is applicable to relations between a parts maker and its suppliers, most of which are small and medium-sized enterprises with little bargaining power.[5] Indeed, in Japanese manufacturing, small and

[5]But in Japanese automobile manufacturing, many first-tier suppliers participate even in the product development (Asanuma 1989; Kim B. Clark and Takahiro Fujimoto 1991). This suggests that these suppliers have some bargaining power against the assembly firms. Therefore, our assumption of a take-it-or-leave-it price may not successfully describe relations between an automobile manufacturer and its first-tier suppliers. We also made the analysis assuming that the price of customized intermediate goods is determined by Nash bargaining between an assembly firm and its suppliers. The result was qualitatively the same as in this paper.

medium-sized enterprises constitute more than 90 percent of all enterprises.[6] These parts makers and its suppliers have increased specificity of intermediate goods in their long-term business relationships.

2.2 Assembly Firm's Profit Maximization

In specific production, the assembly firm purchases n inputs at the price p and sells n units of the final good at the price $(1+\theta)v$, so its profit is $n(1+\theta)v - np$. In market production, the assembly firm purchases n inputs from the market, in which the expected price of each input is $1/2$, and sells n units of the final good at the price v, so the expected profit is $nv - n/2$. Therefore, given the price p, the (unconditional) expected profit is given by

$$\pi = S[n(1+\theta)v - np] + (1-S)\left(nv - \frac{n}{2}\right), \tag{1}$$

where S denotes the probability that specific production takes place.

The probability S depends on p. Given the price p, the probability that p exceeds c for each supplier (and thereby it can produce the customized good) is given by $\Pr(c \leq p) = \min(1, p)$. Hence, the probability that p exceeds c for all n suppliers and specific production takes place in the assembly firm can be written as

$$S = \min(1, p^n). \tag{2}$$

Taking equation (2) into account, the assembly firm determines p to maximize equation (1). Note here that equation (2) may have different functional forms depending on whether p exceeds one. Therefore, we have to examine each case separately.

Case 1. $p > 1$. Substituting $S = 1$ into equation (1), we get

$$\pi = n(1+\theta)v - np. \tag{3}$$

The expected profit π in equation (3) is a linear function of p with a slope of $-n$.

Case 2. $p \leq 1$. Substituting $S = p^n$ into equation (1) we obtain

$$\pi = n\left[-p^{n+1} + \left(\theta v + \frac{1}{2}\right)p^n + v - \frac{1}{2}\right]. \tag{4}$$

In equation (4), π is a polynomial function of p with degree $(n+1)$, which is concave with

[6] In 2009, enterprises with 4 to 299 employees constituted 95.2 percent of all enterprises (excluding those with 3 employees or less) in Japanese motor vehicles, parts, and accessories industry. The source is the Ministry of Economy, Trade and Industry "Census of Manufactures."

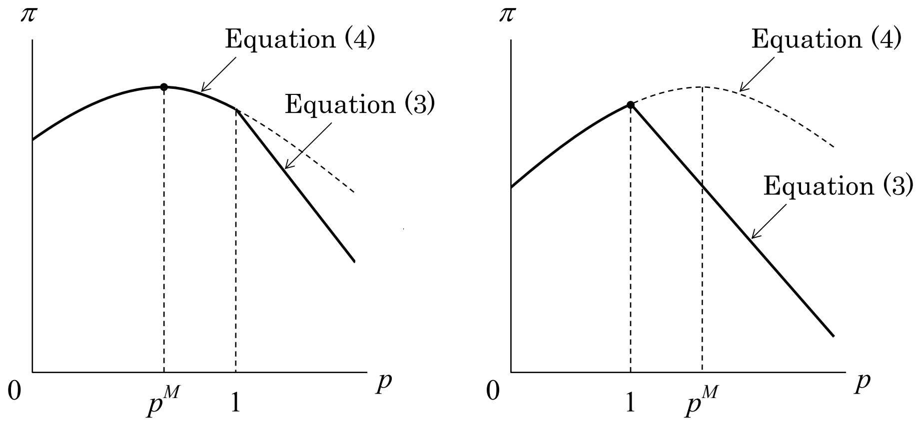

Figure III: The Profit-maximizing Price of the Intermediate Goods for the Cases $p^M < 1$ and $p^M \geq 1$.

a maximum at[7]

$$p = p^M \equiv \frac{n}{n+1}\left(\theta v + \frac{1}{2}\right).$$

Figure 3 shows the expected profit π as the function of the price p for both intervals together (note that $p^M > 0$, since $n, \theta, v > 0$). It is clear from the figure that π is maximized at $p = p^M$ if $p^M < 1$ and $p = 1$ otherwise. Therefore, the optimal price p^* for the assembly firm can be written as

$$p^* = \min(1, p^M) = \min\left[1, \frac{n}{n+1}\left(\theta v + \frac{1}{2}\right)\right]. \tag{5}$$

In equation (5), the price is set at $p^* = 1$ when

$$v \geq \frac{1}{\theta}\left(\frac{1}{n} + \frac{1}{2}\right) \tag{6}$$

holds.[8]

The price to maximize the expected profit is determined as shown above. However, the price does not always make a non-negative expected profit. The non-negative profit condition (NNPC) for $n > 2$ is given by

$$v \geq \begin{cases} \frac{1}{2}, & \text{if } \theta \leq 1 + \frac{2}{n} \\ \frac{1}{\theta}\left(\frac{1}{n} + \frac{1}{2}\right), & \text{if } 1 + \frac{2}{n} < \theta \leq 1 + \frac{4}{n-2} \\ \frac{1}{1+\theta}, & \text{if } 1 + \frac{4}{n-2} < \theta, \end{cases}$$

[7] Taking the derivative of equation (4) with respect to p, we get

$$\pi'(p) = n\left[-(n+1)p^n + n\left(\theta v + \frac{1}{2}\right)p^{n-1}\right].$$

Solving $\pi'(p) \geq 0$ and $\pi'(p) < 0$, we find that $p \leq p^M \iff \pi'(p) \geq 0$ and $p > p^M \iff \pi'(p) < 0$.

[8] In equation (5), the price is set at $p^* = 1$ if $p^M \geq 1$. Solving $p^M \geq 1$, we get equation (6).

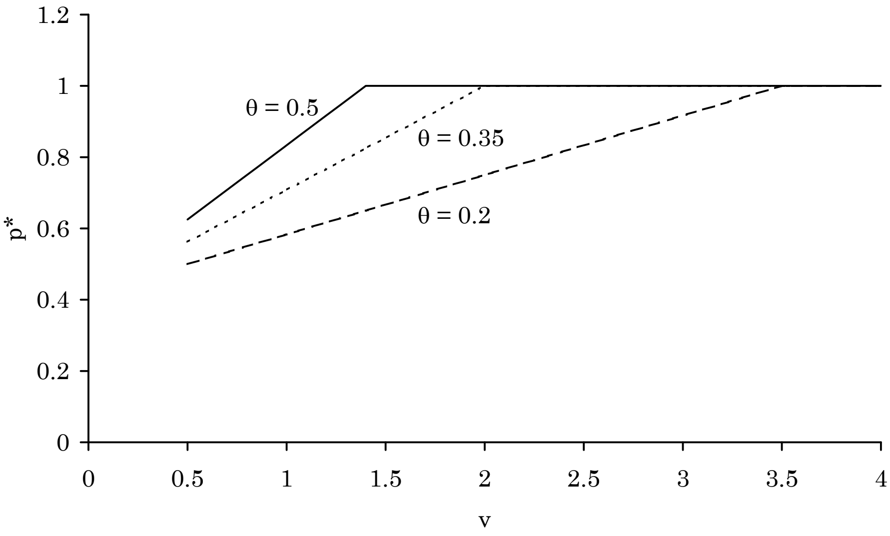

Figure IV: Behavior of Intermediate Goods Price for Different Values of θ.

and for $n \leq 2$ by

$$v \geq \begin{cases} \frac{1}{2}, & \text{if } \theta \leq 1 + \frac{2}{n} \\ \frac{1}{\theta}\left(\frac{1}{n} + \frac{1}{2}\right), & \text{otherwise.} \end{cases}$$

(see Appendix for details).

2.3 Intermediate Goods Price and Demand Shocks

We can now turn to the effect of negative demand shocks on the price p^*. Hereafter, we think of decreased v as a decline in the revenue of an assembly firm, because the number of units produced by the firm is fixed to n in our model for simplification.

Figure 4 compares the effects of decreased v on p^* between different values of θ (given the other parameter $n = 5$). This figure (and the following ones) plots only for the range satisfying NNPC in each case (in this figure, NNPC holds for $v \geq 0.5$ in all the three cases). In the figure, the price exhibits the following features.

First, as the value of θ is larger, the value of v that triggers the reduction of p^* is lower (which is also obvious from equation (6)): where the gains from specialization are larger, the assembly firm does not reduce the price until the market conditions worsen more seriously. This is because the breakdown of specific production causes a greater decline in the revenue of the firms with larger θ (and thus those firms are is more reluctant to reduce the price).

Second, for $p^* < 1$, the larger the value of θ, the steeper the slope: once the price is reduced due to decreased demand, the price drops more rapidly where the gains from specialization are larger. This may explain the observed fact in the Japanese economy during the recession of the late 2000s. In our model, industries which had exhibited higher profitability can be thought of as those with higher θ, and the value of shipments

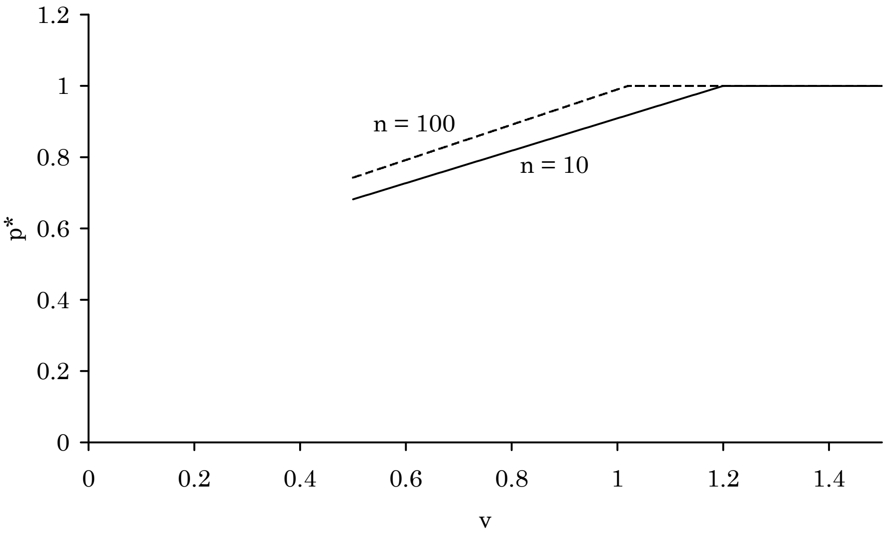

Figure V: Behavior of Intermediate Goods Price for Different Values of n.

from suppliers (i.e., the revenue of suppliers) can be roughly thought of as the value of p^*.[9] In Japan, manufacturing industries with a higher ratio of operating profit to sales (greater than 3 percent) averaged a 24.8 percent decrease in the value of shipments for intermediate goods from 2008 to 2009, whereas those with a lower ratio (less than 3 percent) averaged a 16.2 percent decrease.[10] This is consistent with the second feature in Figure 4. We find another instance in the global semiconductor market.

Demand shocks are not the only cause of reductions in revenue for suppliers. Improved product quality in emerging countries has made it harder for Japanese manufacturers to maintain the competitiveness of their products, especially since the late 2000s. Our model suggests that this decline in the competitiveness of products, which can be thought of as decreased θ, reduces p^* and thus the revenue of suppliers. In Figure 4, when $v = 1.0$, the value of p^* is nearly equal to 0.83 for $\theta = 0.5$, to 0.71 for $\theta = 0.35$, and to 0.58 for $\theta = 0.2$. As shown in this figure, the lower the value of θ, the lower the value of p^* even if v does not decrease.

Figure 5 compares the effects of decreased v on p^* between different values of n (given the other parameter $\theta = 0.5$). From the figure, we can see the following. Firstly, as the

[9] In this model, the number of units produced by each supplier is fixed to one. Thus, the value of shipments per supplier (in expectation) is given by

$$Sp^* + (1-S)\frac{1}{2} = \frac{1}{2} + \min[1, (p^*)^n]\left(p^* - \frac{1}{2}\right),$$

where we assume that, if specific production breaks down, the suppliers shift to producing marketed goods. The above equation shows that the value of shipments increases with p^* for $p^* > n/(2n+2)$.

[10] Operating profit and sales are for fiscal year 2007, and the source is the Ministry of Finance Japan, "Financial Statements Statistics of Corporations by Industry." The value of shipments for intermediate goods (producer goods) is obtained from the Ministry of Economy, Trade and Industry, "Indices of Industrial Production," the base year of which is 2005.

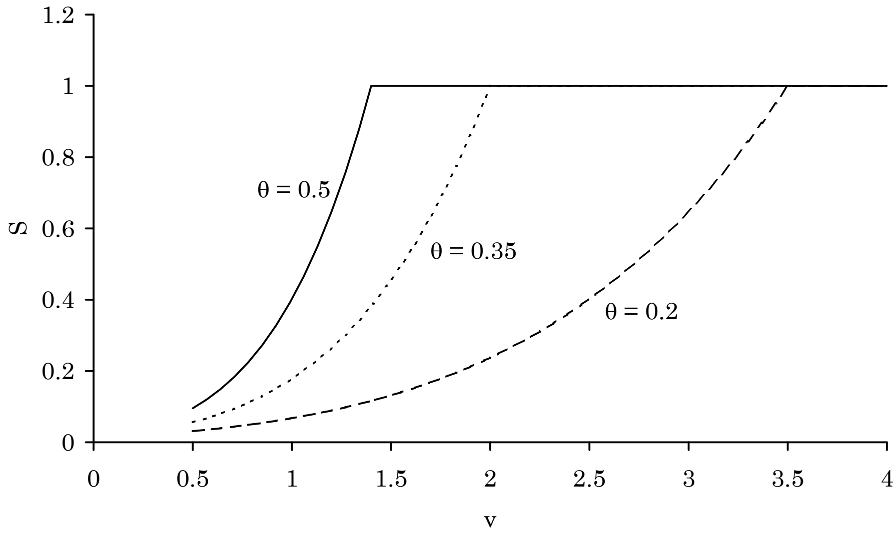

Figure VI: Probability that Specific Production Will Take Place for Different Values of θ.

value of n is larger, the value of v that triggers the reduction of p^* is lower (which is also obvious from equation (6)): where the production process of the final goods is more complex, the assembly firm does not reduce the price until the market conditions worsen more seriously. This is for the following reason. The larger the value of n, the lower the probability that specific production takes place if all the other parameters are held fixed. Hence, reductions in p^* are more likely to cause a breakdown of specific production where n is larger. Therefore, the firm with larger n is more likely to keep p^* at one to avoid revenue reduction due to the breakdown of specific production.

Secondly, for $p^* < 1$, the larger the value of n, the greater the decline in p^* as v decreases: once the price is reduced due to decreased demand, the price decreases more rapidly in firms with a more complex production process.

2.4 Probability that Specific Production Will Take Place

We now turn to how negative demand shocks reduce the probability that specific production will take place. Substituting $p = p^*$ into equation (2), we get,[11]

$$S = \min\left\{1, \left[\frac{n}{n+1}\left(\theta v + \frac{1}{2}\right)\right]^n\right\}. \tag{7}$$

In equation (7), the probability S is equal to one if $p^* = 1$ (when equation (6) holds).

Figure 6 compares the effects of decreased v on S between different values of θ (given

[11] Substituting $p = p^*$ and equation (5) into equation (2) yields

$$S = \min\left\{1, \left\{\min\left[1, \frac{n}{n+1}\left(\theta v + \frac{1}{2}\right)\right]\right\}^n\right\}.$$

Rearranging, we get the equation (7).

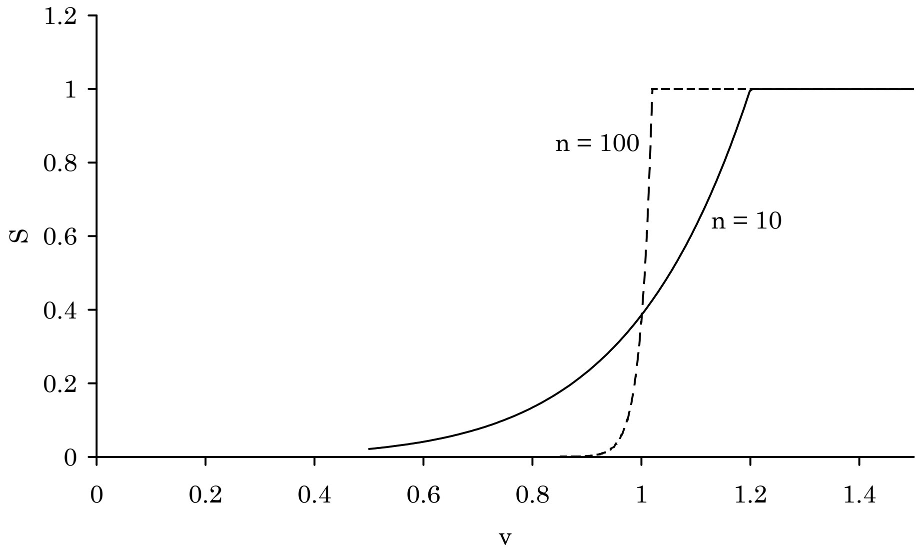

Figure VII: Probability that Specific Production Will Take Place for Different Values of n.

the other parameter $n = 5$). The features shown in the figure are as follows.First, as the value of θ is larger, the value of v that triggers the decline in S is lower (which is also obvious from equation (6)): where the gains from specialization are larger, specific production is less likely to break down when the market conditions are worsening. Second, for $S < 1$, the larger the value of θ, the greater the decline in S as v decreases: once S falls below one, specific production breaks down more rapidly where the gains from specialization are larger.

Figure 7 compares the effects of decreased v on S between different values of n (given the other parameter $\theta = 0.5$). This figure firstly shows that the larger the value of n, the lower the value of v that triggers the decline in S (which is also obvious from equation (6)): where the production process is more complex, specific production is less likely to break down when the market conditions are worsening. Secondly, for $S < 1$, the larger the value of n, the greater the decline in S as v decreases: once S falls below one, specific production breaks down more rapidly where the production process is more complex.

2.5 Specific Relations vs. Market Transactions

Turning to the expected output (or revenue) of an assembly firm. Let Y_S denote the expected output of the final good produced by specific relations. Specific production takes place with probability S. If it takes place, the assembly firm generates revenue of $n(1+\theta)v$. Thus, we can get

$$Y_S = Sn(1+\theta)v. \tag{8}$$

For market production, let Y_M denote the expected output of the final good produced by market transactions. The assembly firm decides to purchase all inputs from the market

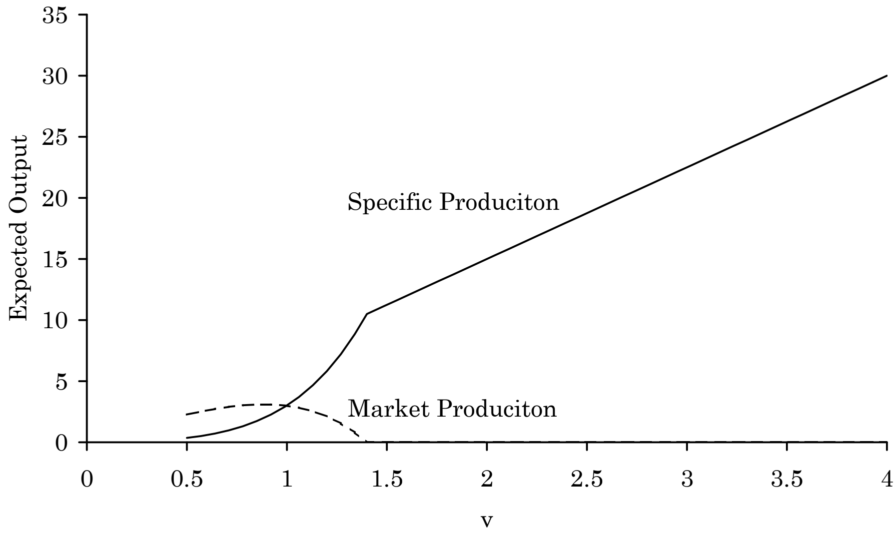

Figure VIII: Expected Output of Specific and Market Production for $\theta = 0.5$.

with probability $(1 - S)$. If it purchases inputs from the market, it generates revenue of nv. Hence, Y_M is given by

$$Y_M = (1 - S)nv. \tag{9}$$

Although Y_S and Y_M are the probabilistic expected values of the output in a typical firm, these can be also thought of as the approximations of total output in one industry. Suppose now that an industry consists of an infinite number of identical assembly firms, where the realizations of c are independent across all the firms,[12] and normalize the number of the firms to one. Then, by the law of large numbers, we can think of Y_S and Y_M as the approximate outputs of the entire industry.[13]

Figure 8 compares the effects of decreased v on Y_S and on Y_M between different values of θ (given the other parameter $n = 5$). In the figures, the outputs exhibit the following features.First, for v above some critical level (i.e., for v that satisfies equation (6)), Y_S decreases linearly with v. For v below it, Y_S turns convex, and Y_M appears. Second, as the value of θ is larger, the value of v at which Y_S turns convex is lower. Third, once Y_S turns convex in each case, it decreases more sharply where θ is larger. This is because the breakdown of specific production causes a larger decline in the product value of the final good where θ is larger.

Figure 9 compares the effects of decreased v on Y_S and on Y_M between different values of n (given the other parameter $\theta = 0.5$). From the figures, we can firstly see that as the

[12] In other words, it is assumed that, in specific production, no intermediate goods are supplied to more than one assembly firm.

[13] Some readers may think that an industry consisting of identical assembly firms has only two extreme states: whether specific production takes place in all the firms or not. Indeed, all the assembly firms in the industry have the same value of p^*. However, given p^*, it is uncertain whether c exceeds p^* (where we assume that $p^* < 1$), because c is the random variable. In consequence, specific production will take place in some assembly firms and not in the others, even if all the identical firms make the same decisions.

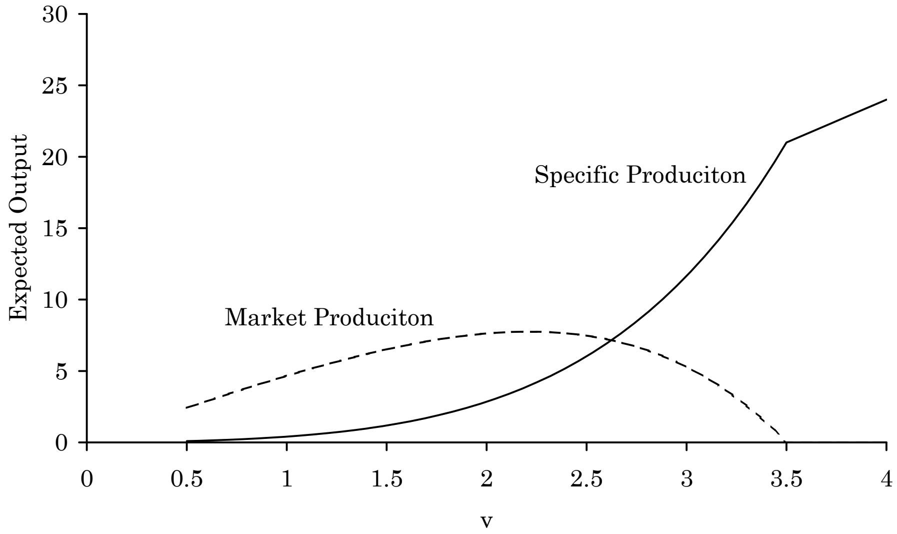

Figure VIII (Continued): Expected Output of Specific and Market Production for $\theta = 0.2$.

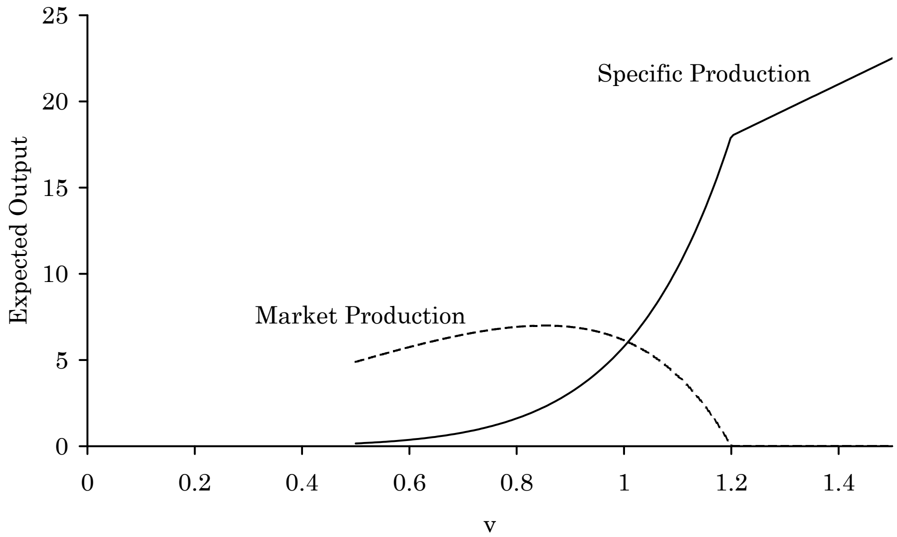

Figure IX: Expected Output of Specific and Market Production for $n = 10$.

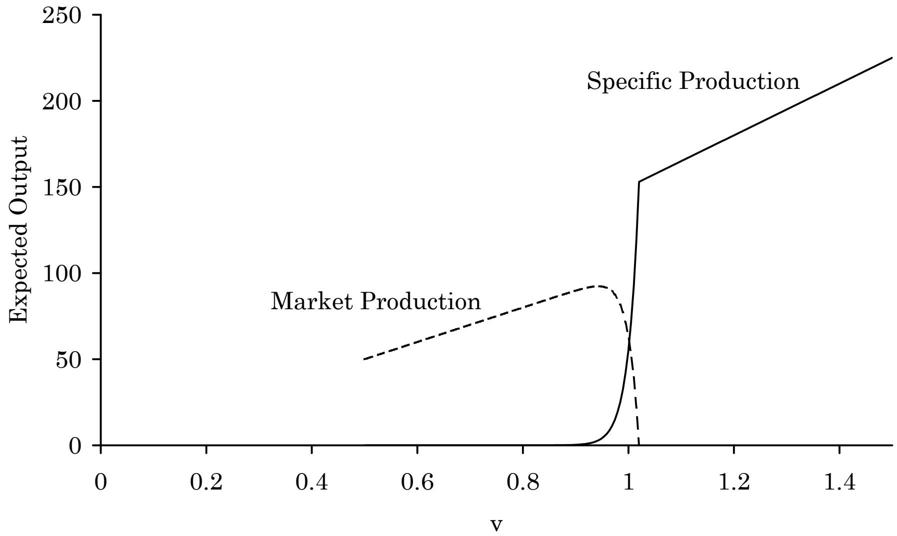

Figure IX (Continued): Expected Output of Specific and Market Production for $n = 100$.

value of n is larger, the value of v at which Y_S turns convex is lower. Secondly, once Y_S turns convex in each case, it decreases more sharply where n is larger. This is because retaining specific production is more difficult (more expensive) where n is larger.

2.6 Total Output in an Industry

We are now ready to define the total output of one industry. If we continue to suppose that an industry consists of an infinite number of assembly firms and to normalize the number of the firms to one, the total output of an industry is given by

$$W = Y_S + Y_M. \tag{10}$$

Figure 10 compares the relative declines in total output W between different values of θ (given the other parameter $n = 5$). In this figure, the output W in each case is normalized to 1 at $v = 3.5$, which is the minimum value of v that satisfies $S = 1$ in both cases where $\theta = 0.5$ and where $\theta = 0.2$. The features exhibited in the figure are as follows. In a mild recession (when v is between 3.5 and nearly 1.12 in the case of this figure), the large-θ case (i.e., the case where the gains from specialization are larger) exhibits a smaller decline in output compared to the small-θ case.

By contrast, in an extremely deep recession (when v is below about 1.12), the small-θ case has a smaller decline in output compared to the large-θ case. This is consistent with the fact that Japan, where specific production has been highly developed, had a larger decline in industrial production than other advanced countries.

Figure 11 compares the relative declines in total output W between different values of n (given the other parameter $\theta = 0.5$). In this figure, the output W in each case is normalized to 1 at $v = 1.2$ (since both cases take $S = 1$ for $v \geq 1.2$). The figure shows

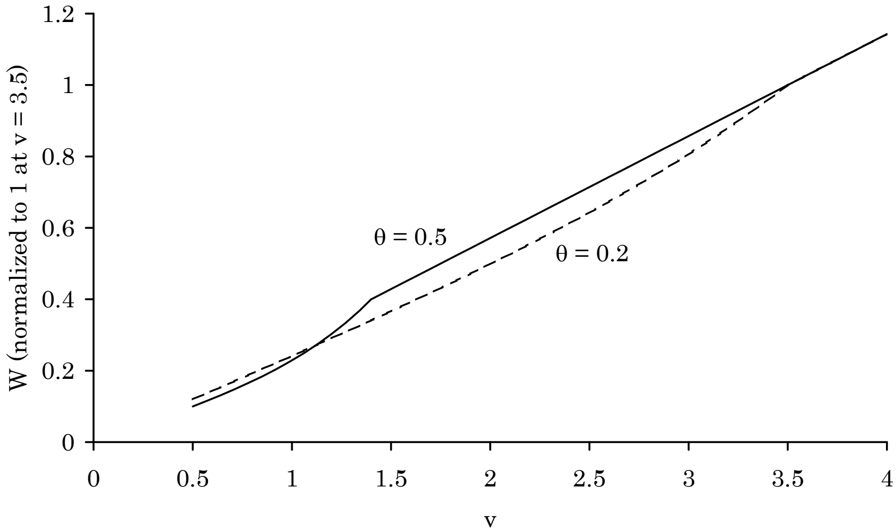

Figure X: Relative Output (Normalized to 1 at $v = 3.5$) for Different Values of θ.
In the figure, both cases are at the same level for $v \geq 3.5$. The case $\theta = 0.2$ has a turning point at $v = 3.5$, being at a lower level than the case $\theta = 0.5$ for v between 3.5 and nearly 1.12. The case $\theta = 0.5$ has a turning point at $v = 1.4$, being at a lower level than the case $\theta = 0.2$ for v below about 1.12.

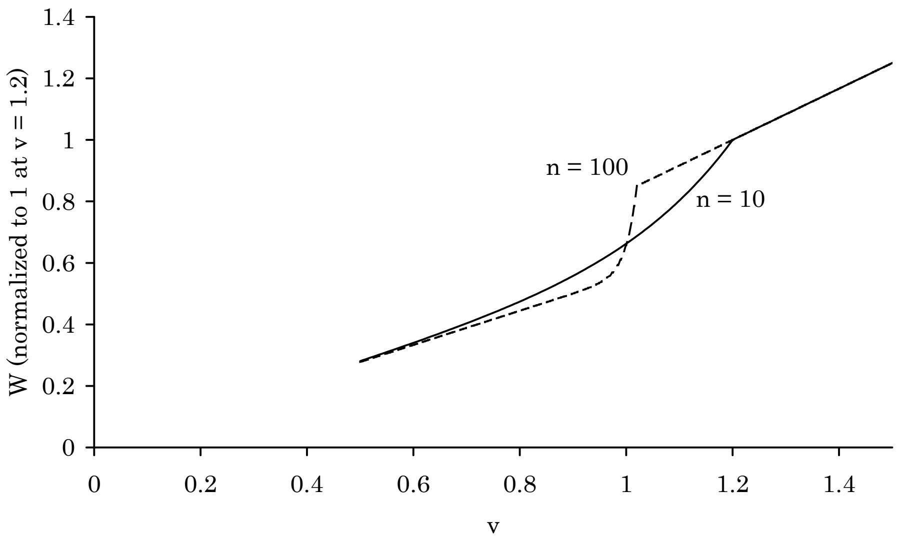

Figure XI: Relative Output (Normalized to 1 at $v = 1.2$) for Different Values of n.
In the figure, both cases are at the same level for $v \geq 1.2$. The case $n = 10$ has a turning point at $v = 1.2$, being at a lower level than the case $n = 100$ for v between 1.2 and nearly 1. The case $n = 100$ has a turning point at $v = 1.02$, being at a lower level than the case $n = 10$ for v below about 1.

that in a mild recession (when v is between 1.2 and nearly 1 in this figure), the large-n case (i.e., the case with a more complex production process) exhibits a smaller decline in output compared to the small-n case. By contrast, in an extremely deep recession (when v is below about 1), the small-n case has a smaller decline in output compared to the large-n case.

2.7 Output Elasticity

Caballero and Hammour (1998) show that specificity, together with incompleteness of contracts, makes economies more responsive to shocks under weak market conditions. Is this finding exhibited in our model? We will also compare the elasticities of total output with respect to negative demand shocks between the specific-production sector and the market-oriented one.[14] The *specific-production sector* consists of assembly firms which choose between specific and market production in a way to maximize their profits. The *market-oriented sector* refers to a sector in which specific production does not take place at all (i.e., S is held fixed to zero) for some institutional reason.

The elasticity of total output with respect to negative demand shocks can be defined as

$$e = \frac{\Delta W/W}{\Delta v/v}.$$

We now let e_S and e_M denote respectively the elasticities in the specific-production sector and in the market-oriented one. The value of e_M is constant at one. This is because, in the market-oriented sector, the output W is always equal to nv, so the change in W caused by a one-percent change in v is constant at one percent. For deriving the elasticity e_S, see Appendix.

Figure 12 compares the output elasticities between different values of θ (given the other parameter $n = 5$). Note here that the figure never indicates the responses to increased demand but only to decreased demand, since this model does not consider the creation of new relations in recovery periods. This figure shows that when the market conditions fall below some critical level in each case (i.e., for $v < 1.4$ in the case $\theta = 0.5$, and for $v < 3.5$ in the case $\theta = 0.2$), the specific-production sectors are more responsive to negative demand shocks than the market-oriented sector. In short, specificity can increase the impact of negative demand shocks. This is because, in the sector where specific relations are used, the output is reduced by not only the demand shock itself but also the decreased product value due to the breakdown of specific production.

On the other hand, under extremely weak market conditions (i.e., for $v < 1.4$), the large-θ case (i.e., the case where the gains from specialization are larger) is more responsive to negative demand shocks than the small-θ case. This is because the breakdown of specific

[14] Specificity is characterized by a joint surplus from an economic relationship in Blanchard and Kremer (1997) and by irreversible investment in Caballero and Hammour (1998). Our modeling follows the former approach. Therefore, we compare the output elasticities between cases where the surplus from specificity is available and where it is not. By contrast, Caballero and Hammour make a comparison between cases where irreversible investment causes holdup and where it does not.

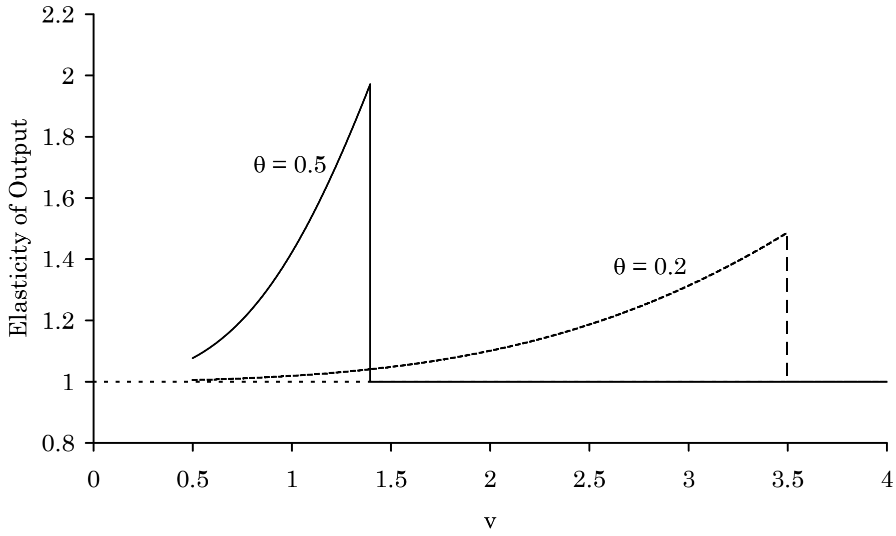

Figure XII: Output Elasticity with Respect to Negative Shocks for Different Values of θ.

production causes a larger decline in the product value where θ is larger.
The results we obtained above are consistent with Caballero and Hammour's finding that specificity, together with incomplete contracts, makes recessions excessively sharp.

Figure 13 compares the elasticities between different values of n (given the other parameter $\theta = 0.5$). The figure shows again that, when the market conditions fall below some critical level in each case (i.e., for v below about 1.2 in the case $n = 10$, and for v below about 1.02 in the case $n = 100$), the specific-production sectors are more responsive to negative shocks than the market-oriented sector. By contrast, roughly speaking, under extremely weak market conditions (i.e., for v between about 1.02 and about 0.95), the large-n case (i.e., the case with a more complex production process) is more responsive to negative shocks than the small-n case.

3 Another Production Technology: Robustness of Findings

In our basic model, we make the extreme assumption that, if one or more of the customized intermediate goods are not available, the market value of the final goods falls to the lowest level. But even if this extreme assumption is weakened, we arrive at the same results as shown in the basic model. This section provides a second model with the weaker assumption that the market value of the final goods increases linearly as the fraction of customized intermediate goods increases.

3.1 Technology and Intermediate Goods Transactions

An assembly firm needs n intermediate goods in order to produce n units of a final good, which is the same as the basic model. But the final goods in this second model are sold

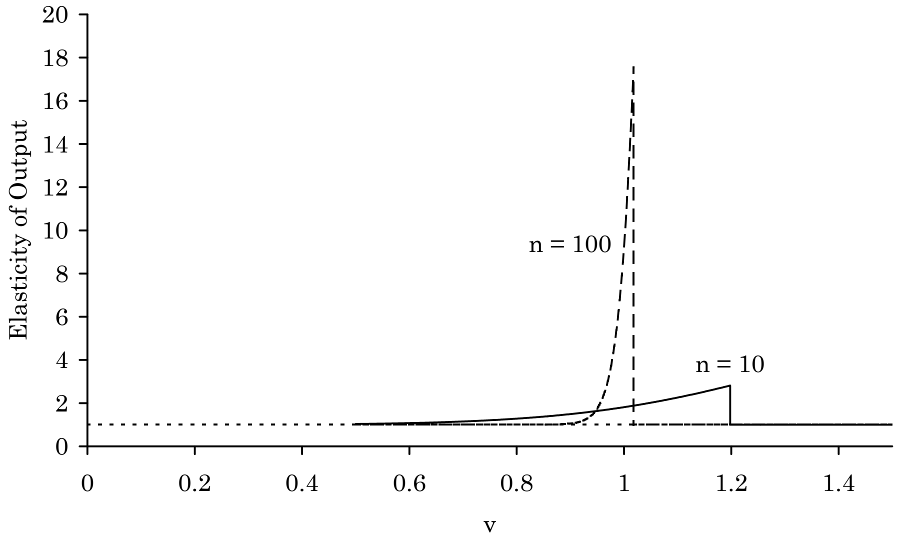

Figure XIII: Output Elasticity with Respect to Negative Shocks for Different Values of n.

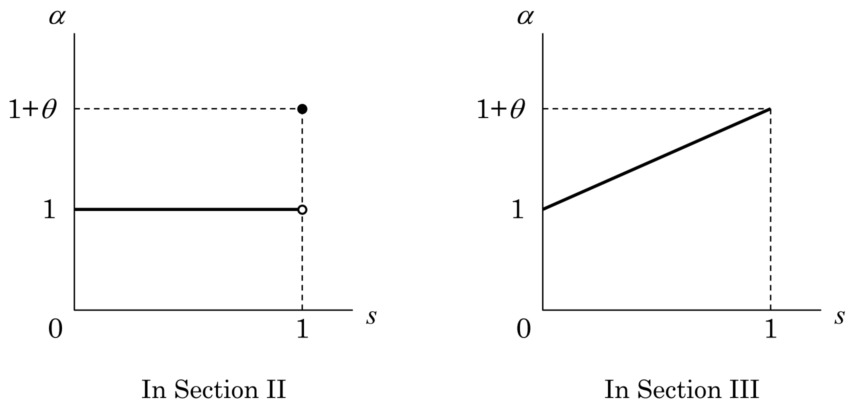

Figure XIV: Fraction of Customized Inputs and Market Value of Final Goods.

at the price of αv, and the parameter α is defined as

$$\alpha(s) = 1 + \theta s,\ \theta > 0, \tag{11}$$

where s denotes the fraction of customized inputs to all n inputs. That is, the price of the final good is equal to v if none of the inputs are customized by specific suppliers. If all inputs are customized, increasing linearly with s, the price goes to $(1 + \theta)v$ (see also Figure 14).

This section continues the previous discussion on transactions of intermediate goods: the assembly firm announces a take-it-or-leave-it price p to each supplier; each input is produced at the cost c, distributed uniformly on $[0, 1]$; the suppliers with $c > p$ cannot produce the customized intermediate goods.

In the previous section, if one or more suppliers cannot produce customized goods, the assembly firm decides to purchase all inputs from the market. This is because, when one or more inputs cannot be customized, the market value of the final goods falls to the lowest level regardless of whether the other inputs are customized. But in this section, even if some inputs cannot be customized, the other customized inputs still contribute to the market value of the final goods, given the assumption that the value of the final goods increase linearly with the fraction of customized inputs. Therefore, in this model, the assembly firm uses marketed intermediate goods only for the inputs that specific suppliers cannot provide (i.e., the assembly firm can combine customized and marketed intermediate goods in order to produce the final goods).

3.2 Assembly Firm's Profit Maximization

The assembly firm sells n units of the final good at the price αv. Hence, from equation (11), its expected revenue is $n\alpha v = n(1+\theta s)v$. On the other hand, it purchases sn inputs at the price p, and $(1-s)n$ inputs from the market in which the expected prices of inputs are equal to 1/2. Therefore, given the price p, the expected profit of the assembly firm is given by

$$\pi = n(1+\theta s)v - \left[snp + (1-s)\frac{n}{2}\right]. \qquad (12)$$

We now turn to the fraction s. Given the price p, the probability that p exceeds c for each supplier is given by $\Pr(c \le p) = \min(1, p)$. Therefore, the expected fraction of customized inputs to all n inputs is equal to[15]

$$s = \min(1, p). \qquad (13)$$

Equation (13) may have different functional forms depending on whether p exceeds one. Thus, we have to examine each case separately.

Case 1. $p > 1$. Substituting $s = 1$ into equation (12), we obtain

$$\pi = n(1+\theta)v - np. \qquad (14)$$

The expected profit π in equation (14) is a linear function of p with a slope of $-n$.

Case 2. $p \le 1$. Substituting $s = p$ into equation (12), we get

$$\pi = n\left[-p^2 + \left(\theta v + \frac{1}{2}\right)p + v - \frac{1}{2}\right]. \qquad (15)$$

[15]Let d_i be a binary variable taking the value of 1 if the i th input is customized and 0 otherwise. The fraction of customized inputs with respect to total number of inputs can be written as $(d_1+d_2+...+d_n)/n$. Thus, the expected fraction of customized inputs is given by $\mathrm{E}[(d_1+d_2+...+d_n)/n] = [\mathrm{E}(d_1)+\mathrm{E}(d_2)+ ... + \mathrm{E}(d_n)]/n$. Substituting $\mathrm{E}(d_i) = \min(1,p)$, we can get $[n \cdot \min(1,p)]/n = \min(1,p)$.

In equation (15), π is a quadratic function of p, which is maximized at[16]

$$p = p^M \equiv \frac{\theta v}{2} + \frac{1}{4}.$$

We have now obtained the expected profit π as the function of the price p for the cases $p > 1$ and $p \leq 1$. Drawing the functions for both cases together, we obtain a graphical representation similar to Figure 3. Therefore, the price to maximize the expected profit is $p = p^M$ if $p^M < 1$ and $p = 1$ otherwise. That is, the optimal price p^* can be written as

$$p^* = \min(1, p^M) = \min\left(1, \frac{\theta v}{2} + \frac{1}{4}\right), \tag{16}$$

where the price is set at $p^* = 1$ when

$$v \geq \frac{3}{2\theta} \tag{17}$$

holds.[17] In addition, NNPC is given by

$$v \geq \frac{-\theta - 4 + 2\sqrt{2\theta(1+\theta) + 4}}{2\theta^2},$$

(see Appendix for details).

3.3 The Price and the Fraction of Customized Inputs

In the basic model, either specific or market production takes place. But in this section, the assembly firm can combine customized and marketed intermediate goods in order to produce the final goods. Thus, we will here consider the effects of demand shocks on the fraction of customized inputs, instead of on the probability that specific production takes place.

Substituting $p = p^*$ into equation (13), we get the expected fraction of customized inputs,[18]

$$s = \min\left(1, \frac{\theta v}{2} + \frac{1}{4}\right). \tag{18}$$

The right-hand side of equation (18) is identical to that of equation (16), so we deal

[16] Taking the derivative of the above equation with respect to p, we get

$$\pi'(p) = n\left(-2p + \theta v + \frac{1}{2}\right).$$

Solving $\pi'(p) = 0$, we obtain the equation in the body text.

[17] In equation (16), the price is set at $p^* = 1$ if $p^M \geq 1$. Solving $p^M \geq 1$ with respect to v, we get equation (17).

[18] Substituting $p = p^*$ and equation (16) into equation (13) yields

$$s = \min\left[1, \min\left(1, \frac{\theta v}{2} + \frac{1}{4}\right)\right].$$

Rearranging, we get equation (18).

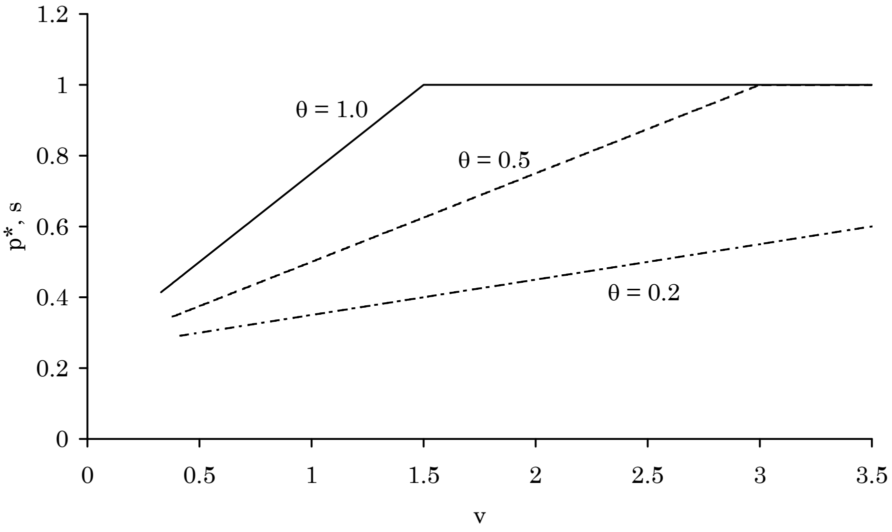

Figure XV: The Price and the Fraction of Customized Inputs for a Linear Production Technology.

with both the price and the fraction of customized intermediate goods at the same time. Figure 15 compares the effects of decreased v on p^* or on s between different values of θ. This figure (and the following ones) plots only for the range satisfying NNPC (in this figure, NNPC holds for v above about 0.328 in the case $\theta = 1.0$, about 0.381 in the case $\theta = 0.5$, and about 0.415 in the case $\theta = 0.2$). From the figure, we can see the same features as shown in the basic model: the larger the value of θ, the lower the value of v that triggers a decline in the price p^* (or the fraction s); the larger the value of θ, the greater the decline in p^* (or s) as v decreases.

In the previous section, we compared different values of n. However, in this section, the parameter n does not affect the price p^* nor the fraction s. For this reason, here and hereafter, we make no comparison between different values of n. Moreover, we cannot here examine how decreased demand affects the expected output of specific production and that of market production. This is the result of the assumption that in this section, an assembly firm can combine customized and marketed inputs to produce the final goods, whereas in the previous section, only one, specific or market production takes place.

3.4 Total Output in an Industry

Like in the previous section, we suppose there is an industry consisting of an infinite number of assembly firms, and normalize the number of the firms to one. Then we can think of the expected output of an assembly firm as the total output in an industry. A typical assembly firm sells n final goods at the price αv. Thus, from equation (11), the total output of the industry is given by

$$W = n\alpha(s)v = n(1 + \theta s)v. \tag{19}$$

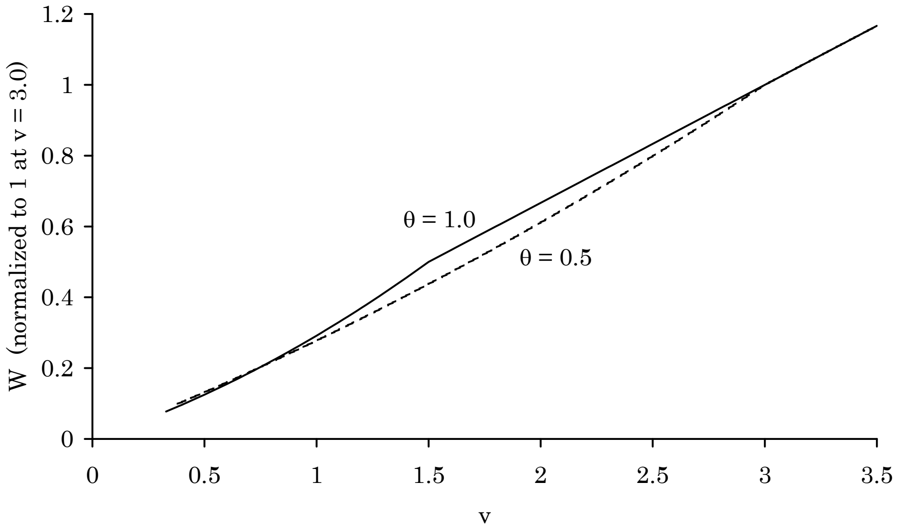

Figure XVI: Relative Output (Normalized to 1 at $v = 3.0$) for a Linear Production Technology. Both cases are at the same level for $v \geq 3.0$. The case $\theta = 0.5$ has a turning point at $v = 3.0$, being at a lower level than the case $\theta = 1.0$ for $0.75 < v < 3.0$. The case $\theta = 1.0$ has a turning point at $v = 1.5$, being at a lower level than the case $\theta = 0.5$ for $v < 0.75$.

Figure 16 compares the relative declines in total output W between different values of θ (given the other parameter $n = 1$). In this figure, the output W is normalized to 1 at $v = 3.0$ (since both cases take $s = 1$ for $v \geq 3.0$). The figure exhibits the same features as shown in the basic model: in a mild recession (i.e., for $0.75 < v < 3.0$ in the case of this figure), the large-θ case has a small relative decline in output compared to the small-θ case; in an extremely deep recession (i.e., for $v < 0.75$), the small-θ case has an advantage.

3.5 Output Elasticity

Turning to the elasticities of the total output with respect to negative demand shocks, we compare those between the specific-production sector and the market-oriented one.

First, we derive the total output in the specific-production sector in order to obtain its output elasticity e_S. Substituting equation (18) into equation (19) yields[19]

$$W = n \cdot \min\left[(1+\theta)v, \frac{\theta^2}{2}v^2 + \frac{1}{4}(\theta+4)v\right]. \tag{20}$$

If equation (17) holds (i.e., when $s = 1$), equation (20) becomes a linear function of v, so $e_S = 1$ (because the change in W caused by a one-percent change in v is constant at one). If equation (17) does not hold (i.e., when $s < 1$), substituting equation (20) and its

[19]Substituting equation (18) into equation (19) yields

$$W = n\left[1 + \theta \cdot \min\left(1, \frac{\theta v}{2} + \frac{1}{4}\right)\right]v.$$

Rearranging that, we get equation (20).

derivative with respect to v into $e_S = (\Delta W/W)/(\Delta v/v)$, we get[20]

$$e_S = 1 + \frac{2\theta^2 v}{2\theta^2 v + \theta + 4}. \tag{21}$$

Thus, the elasticity in the specific-production sector can be finally written as

$$e_S = \begin{cases} 1, & \text{if } v \geq \frac{3}{2\theta} \\ 1 + \frac{2\theta^2 v}{2\theta^2 v + \theta + 4}, & \text{otherwise.} \end{cases}$$

Secondly, we turn to the elasticity in the market-oriented sector. In this sector, a typical assembly firm always sells n final goods at the price v. Thus, the total output can be expressed as $W = nv$. Hence, it is clear that $e_M = 1$.

We are now ready to compare the elasticities between the specific-production and the market-oriented sector. The second term in equation (21) is always positive, since $\theta, v > 0$. Thus, it is clear that $e_S > e_M$ if equation (17) does not hold. On the other hand, if equation (17) holds, e_S and e_M are equal to one. That is, as well as in the previous section, the specific-production sector is more responsive to negative demand shocks than the market-oriented sector when the market conditions fall below some critical level.

In addition, Figure 17 compares the elasticities between different values of θ. From the figure, we can see the same features as in the basic model: as θ is larger, output is more responsive to negative demand shocks under extremely weak market conditions (when $v < 1.5$ in the case of this figure).

4 Evidence on Output Decline from Japanese Manufacturing Industry

One implication we got in the previous section is that an industry with higher specificity has a greater output decline during a major recession. In this section, we provide empirical evidence that the output decline is larger in an industry with a higher percentage of the subcontracting cost in the sales cost. For manufacturers, we can equate the sales cost with the production cost, so the percentage of subcontracting cost in sales cost can be thought of as the proportion of customized inputs in all inputs.

We use data on the sales of 56 Japanese manufacturing industries[21] in the fiscal year 2007 and 2009, and construct the growth rate of output for each industry. The output growth from fiscal year 2007 to 2009 can capture the output decline during the 2008 global recession. The data come from the Basic Survey of Japanese Business Structure

[20] Rewrite e_S as $e_S = \Delta W/\Delta v \cdot v/W$. Substituting equation (20) and $\Delta W/\Delta v = n[\theta^2 v + (\theta+4)/4]$ yields

$$e_S = \frac{4\theta^2 v + \theta + 4}{2\theta^2 v + \theta + 4}.$$

Rearranging that, we get equation (21).

[21] The data source classifies printing industry into manufacturing, but we exclude printing industry from our data set.

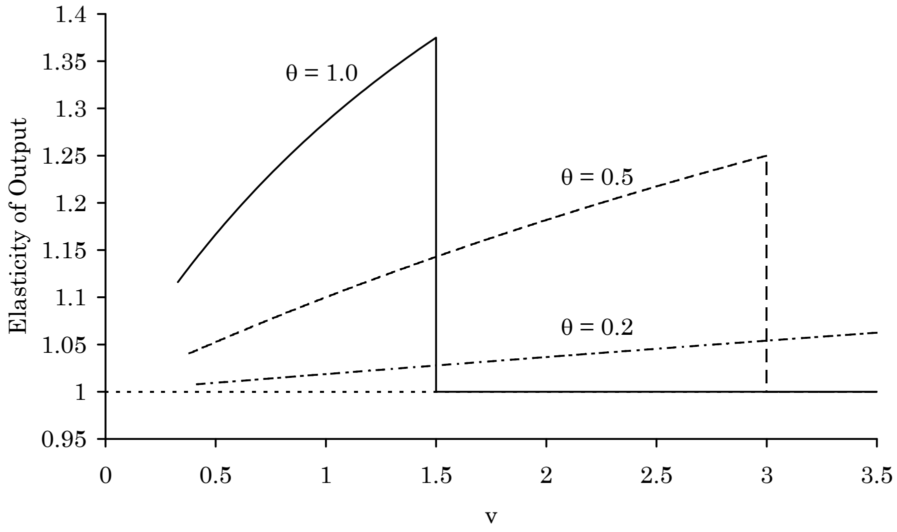

Figure XVII: Output Elasticity with Respect to Negative Shocks for a Linear Production Technology.

and Activities by the Ministry of Economy, Trade and Industry.

We regress the output growth on the percentage of subcontracting cost in the sales cost and three additional control variables.

For the percentage of the subcontracting cost in the sales cost, we take data for the fiscal year 2007 from the Basic Survey of Japanese Business Structure and Activities, which is the same as the source of the output growth. Table 1 shows the percentage of the subcontracting cost for each industry. In this table, 56 industries are aggregated into 23 categories. Seeing the ranking, the percentage of the subcontracting cost seems to be a good measure of the customization of inputs. For example, production machinery has the highest percentage of subcontracting cost, and petroleum and coal has the lowest. Overall the percentage of subcontracting cost tends to be higher if the produced goods are more complex.

Durability, the first additional variable, is a dummy that is equal to one if the industry produces durable goods, and zero otherwise. Blanchard and Kremer (1997) also use this dummy in their regression of output growth. An output decline during recessions is typically larger in durable goods industries than non-durable goods industries.

Next two variables, input price growth and output price growth, come from Input-Output Price Index of the Manufacturing Industry by Sector (IOPI) released by the Bank of Japan.[22] Input (output) price growth is the growth rate of the input (output) price index for each industry from fiscal years 2007 to 2009. The effects of these two variables are ambiguous. For example, output price growth is expected to have a positive effect on the output growth if the price elasticity of demand is sufficiently lower than one.

[22]IOPI classifies manufacturing industries into 16 sectors and reports the input price index for each sector. Therefore, the industries which belong to the same sector in IOPI have the same value for input and output price growth.

Table I: Percentage of Subcontracting Cost in Sales Cost

Industry	Percentage
Petroleum and Coal	0.82
Beverages, Tobacco and Feed	2.95
Non-Ferrous Metals	3.72
Chemical	4.04
Food	4.26
Pulp and Paper	4.85
Lumber and Wood Products, Except Furniture	5.12
Miscellaneous Manufacturing Industries	8.42
Rubber	8.56
Iron and Steel	8.87
Leather Tanning, Leather Products and Fur Skins	8.93
Plastic	8.99
Furniture and Fixtures	9.05
Electrical Machinery, Equipment and Supplies	9.53
Ceramic, Stone and Clay	10.51
Electronic parts, Devices and Electronic Circuits	12.22
Textile Mill	13.49
Transportation Equipment	14.79
Fabricated Metal	14.99
Information and Communication Electronics Equipment	17.84
General-Purpose Machinery	20.47
Business Oriented Machinery	21.37
Production Machinery	21.73

Sources: see text.

Table II: Summary Statistics

	Mean	Std Dev	Minimum	Maximum
Output growth	-0.182	0.243	-0.740	0.526
Percentage of subcontracting cost	9.991	5.898	0.770	23.750
Output price growth	-0.030	0.070	-0.197	0.071
Input price growth	-0.055	0.073	-0.310	0.023
Durability	0.554	0.502	0.000	1.000

Sources: see text.

Table 2 shows summary statistics for output growth, the percentage of subcontracting cost, and three additional variables.

The regression results are reported in Table 3. Column 1 shows the result of the simple regression model which has only one explanatory variable, the percentage of subcontracting cost. The estimated coefficient is negative and significant at the 1 percent level. Columns 2 to 8 report the results of the regressions including the additional control variables. Especially durability are highly correlated with the percentage of subcontracting cost (the correlation coefficient between two variables is 0.547), but the negative effect of the percentage of subcontracting cost is still significant at 5 percent level in all the regressions. Summarizing the results in the table, a one percent increase in the percentage of the subcontracting cost leads to a 1.5 to 1.9 percent decrease in output.

Table III: Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	-0.028	-0.010	0.025	0.038	-0.026	-0.009	0.026	0.041
	(0.060)	(0.064)	(0.077)	(0.091)	(0.061)	(0.065)	(0.078)	(0.092)
Percentage of subcontracting cost	-0.015***	-0.016***	-0.018***	-0.019***	-0.015**	-0.016**	-0.017**	-0.018**
	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)
Output price growth		0.370		-0.266		0.362		-0.300
		(0.447)		(0.958)		(0.456)		(0.981)
Input price growth			0.502	0.746			0.497	0.769
			(0.461)	(0.992)			(0.467)	(1.008)
Durability					-0.017	-0.009	-0.011	-0.015
					(0.071)	(0.072)	(0.071)	(0.073)
Adjusted R-squared	0.125	0.119	0.128	0.112	0.109	0.103	0.111	0.095

Dependent variable is Output growth. Sample size is 56. Standard errors are reported in parenthesis.

*, **, *** indicate significance at 10, 5 and 1%, respectively.

5 Conclusions

In this paper, we tried to explain how specificity affects the response of production to negative demand shocks. In Section II, we set up our basic model of specific relations between an assembly firm and its suppliers, showing that those specific relations exhibit the following features.

First, specific production in which the gains from specialization are larger does not break down until the market conditions become even more critical. But highly specific production dissolves more rapidly once the market conditions fall below some critical level (these features are shown in Figure 6).

Second, in an extremely deep recession, highly specific production has a larger percentage decline in the value of output, but it has a smaller percentage decline in a mild recession (from Figure 10). In short, specificity of production is advantageous in favorable market conditions, whereas it is disadvantageous in depressions. This is consistent with the Japanese experience of the late 2000s recession. The industries which had exhibited higher profitability (i.e., industries with higher specificity)[23] were more likely to have a larger decline in production.

Third, under extremely weak market conditions, the value of output is more responsive to negative demand shocks in an industry with higher specificity than that with lower specificity (from Figure 12). This is because the decline in product value due to the breakdown of specific production is larger in an industry with higher specificity.

Our basic model assumes that, if one or more intermediate goods cannot be customized, the market value of the final goods falls to the lowest level. In Section III, weakening this assumption, we also consider another model with the assumption that the market value of the final goods increases linearly with the fraction of customized intermediate goods. This analysis produces the same results as in Section II, indicating the robustness of our findings.

In the late 2000s global recession, Japanese economy had a larger decline in industrial production compared to other advanced countries. The results of our analysis suggest that highly specific production in Japan may have played an important role in this poor economic performance. Although Japanese economy in the late 2000s did not have a sharp increase in bankruptcies, we can observe a trend to move from specific inputs to standardized or semi-standardized ones as seen in semiconductor market.

Our theoretical model can be also applied to a number of other discussions. It can explain the impact of the decline in product competitiveness due to improved product

[23]From our model, we can derive that an industry with higher specificity has higher profitability in favorable market conditions (when specific production surely takes place). Substituting $p = p^* = 1$ into equation (3) gives $\pi = n(1+\theta)v - n$. In addition, from equation (8) to (10) and $S = 1$, we get $W = n(1+\theta)v$. Thus, the ratio of profits to output in an industry is given by

$$\frac{\pi}{W} = \frac{n(1+\theta)v - n}{n(1+\theta)v} = 1 - \frac{1}{(1+\theta)v}.$$

The profit ratio in the above equation increases with θ, since $v > 0$.

quality in emerging countries, as mentioned in Section II. It can be applied to the analysis on the impacts of foreign currency depreciation, since we can think of decreased v as the reduction in the revenue of manufacturers from their export goods due to foreign currency depreciation. This is the same for increased competition from globalization. A decrease in v can be thought of as the revenue reduction caused by increased competition.

The weakness of higher specificity is an issue that many economists are interested in. Recent literature on "product modularity" (e.g., Carliss Y. Baldwin and Kim B. Clark 2000; Masahiko Aoki 2001; Takahiro Fujimoto and Jewheon Oh 2004) are, in some ways, studies that attempt to seek a way to overcome the weakness of highly specific production.

The creation of new specific relations is beyond the scope of this paper, while we investigated how decreased demand affects pre-existing relations. In future work, there is a need to take into account how improved demand creates new relations.

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Appendix

Deriving Non-negative Profit Condition in Section II

We here derive NNPC in Section II. At the beginning, we consider the following three cases. If $p^* = 1$ (i.e., if equation (6) holds), specific production surely takes place (Case 1). On the other hand, if $p^* < 1$ (i.e., if equation (6) does not hold), it may take place (Case 2) or not (Case 3).

Case 1. If $p^* = 1$, specific production surely takes place (i.e., $S = 1$), and thereby the expected profit of the assembly firm is equal to $n(1+\theta)v - n$. Thus, NNPC in this case is given by

$$v \geq \frac{1}{1+\theta}. \tag{22}$$

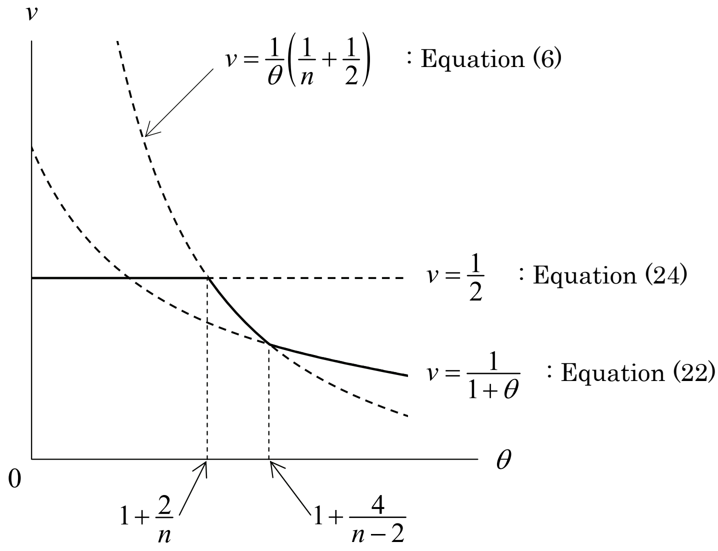

Figure A I: Non-negative Profit Condition in Section II.

Case 2. If $p^* < 1$ and specific production takes place, NNPC is given by $n(1+\theta)v - np \geq 0$. Substituting $p = p^*$ and equation (5) into it yields

$$v \geq \frac{1}{2 + 2(1+\theta)/n}. \tag{23}$$

Case 3. If $p^* < 1$ and specific production does not take place, the expected profit becomes $nv - nc$. Hence, NNPC in this case is given by

$$v \geq \frac{1}{2}, \tag{24}$$

since the expectation of c is equal to $1/2$.

We have now obtained NNPC in all three cases. Comparing NNPC between in Case 2 and in Case 3, we can see that equation (A2) is satisfied whenever equation (A3) holds (since, from $n, \theta > 0$, it follows that the right-hand side of equation (A3) is always greater than that of equation (A2)). Therefore, a sufficient condition for non-negative profit if $p^* < 1$ is given simply by equation (A3).

Taking all three cases into account, NNPC in Section II is given by equation (A1) if equation (6) holds and by equation (A3) otherwise. Figure A1 plots the right-hand sides of equation (6), (A1), and (A3) on the vertical axis against θ on the horizontal axis (note that, if $n \leq 2$, there is no intersection between equation (6) and (A1) for $\theta > 0$). From the figure, it is clear that NNPC for $n > 2$ can be written as

$$v \geq \begin{cases} \frac{1}{2}, & \text{if } \theta \leq 1 + \frac{2}{n} \\ \frac{1}{\theta}\left(\frac{1}{n} + \frac{1}{2}\right), & \text{if } 1 + \frac{2}{n} < \theta \leq 1 + \frac{4}{n-2} \\ \frac{1}{1+\theta}, & \text{if } 1 + \frac{4}{n-2} < \theta, \end{cases}$$

and for $n \leq 2$ as

$$v \geq \begin{cases} \frac{1}{2}, & \text{if } \theta \leq 1 + \frac{2}{n} \\ \frac{1}{\theta}\left(\frac{1}{n} + \frac{1}{2}\right), & \text{otherwise.} \end{cases}$$

The figure also provides important insights. For $1 + 2/n \leq \theta < 1 + 4/(n-2)$, NNPC is given by equation (6) itself. For $\theta \geq 1 + 4/(n-2)$, NNPC is broken when equation (6) is still satisfied. That is, for $\theta \geq 1 + 2/n$, specific production surely takes place (i.e., S is kept at 1) whenever NNPC holds.

Deriving Output Elasticity in Section II

This subsection derives the output elasticity with respect to negative demand shocks in the specific production sector in Section II.

If equation (6) holds, specific production takes place in all assembly firms (i.e., $S = 1$). Hence, the total output in the industry is equal to $W = n(1+\theta)v$ (where the number of firms in the industry is normalized to one). Therefore, it is obvious that $e_S = 1$ if equation (6) holds.

On the other hand, if equation (6) does not hold, then $S = p^n$. Substituting $p = p^*$ and equation (5) into $S = p^n$ yields

$$S = \left(\frac{n}{n+1}\right)^n \left(\theta v + \frac{1}{2}\right)^n.$$

This can be rewritten as

$$S = \left(\frac{n}{n+1}\right)^n \textstyle\sum_{i=0}^{n} \left[\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}\left(\frac{1}{2}\right)^i\right],$$

where $\mathbf{P}_{j,k}$ denotes the (j,k) entry of the symmetric Pascal matrix defined as

$$\mathbf{P} = \begin{bmatrix} 1 & 1 & 1 & \cdots \\ 1 & 2 & 3 & \cdots \\ 1 & 3 & 6 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}.$$

Substituting S and equation (8) and (9) into equation (10), we get

$$W = nv + \left(\frac{n}{n+1}\right)^n \textstyle\sum_{i=0}^{n} \left[\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n+1-i}\left(\frac{1}{2}\right)^i\right] n\theta.$$

Substituting the above equation and its derivative with respect to v into $e_S = \Delta W/\Delta v \cdot v/W$ yields

$$e_S = \frac{1 + [n/(n+1)]^n \sum_{i=0}^{n}[(n+1-i)\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}(1/2)^i]\theta}{1 + [n/(n+1)]^n \sum_{i=0}^{n}[\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}(1/2)^i]\theta}.$$

Rearranging that, we obtain

$$e_S = 1 + \frac{[n/(n+1)]^n \sum_{i=0}^{n} [(n-i)\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}(1/2)^i]\theta}{1 + [n/(n+1)]^n \sum_{i=0}^{n} [\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}(1/2)^i]\theta}. \tag{25}$$

The second term in equation (A4) is always positive, since $n, \theta, v > 0$. Hence, it is clear that $e_S > e_M$ if equation (6) does not hold.

The elasticity in the specific-production sector can be finally written as

$$e_S = \begin{cases} 1, & \text{if } v \geq \frac{1}{\theta}\left(\frac{1}{n} + \frac{1}{2}\right) \\ 1 + \frac{[n/(n+1)]^n \sum_{i=0}^{n} [(n-i)\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}(1/2)^i]\theta}{1 + [n/(n+1)]^n \sum_{i=0}^{n} [\mathbf{P}_{n+1-i,1+i}\theta^{n-i}v^{n-i}(1/2)^i]\theta}, & \text{otherwise.} \end{cases}$$

Deriving Non-negative Profit Condition in Section III

In this subsection, we derive NNPC in Section III. At the beginning, we consider the two cases that equation (17) holds (i.e., $p^* = 1$) and that it does not (i.e., $p^* < 1$).

Case 1. $p^* = 1$. Substituting $p = p^* = 1$ into equation (14) yields the expected profit $\pi = n(1+\theta)v - n$. Thus, NNPC for this case is given by

$$v \geq \frac{1}{1+\theta}. \tag{26}$$

However, equation (A5) is satisfied whenever equation (17) holds (the right-hand side of equation (17) is always greater than that of equation (A5), since $\theta > 0$). That is, the expected profit is always non-negative if equation (17) holds.

Case 2. $p^* = p^{*M}$. Substituting $p = p^*$ and equation (16) into equation (15) gives the expected profit. Hence, NNPC for this case can be written as

$$n\left[-\left(\frac{\theta v}{2} + \frac{1}{4}\right)^2 + \left(\theta v + \frac{1}{2}\right)\left(\frac{\theta v}{2} + \frac{1}{4}\right) + v - \frac{1}{2}\right] \geq 0.$$

Rearranging that gives

$$4\theta^2 v^2 + (4\theta + 16)v - 7 \geq 0.$$

Solving the above inequality with respect to v, we get[24]

$$v \geq \frac{-\theta - 4 + 2\sqrt{2\theta(1+\theta) + 4}}{2\theta^2}.$$

This is NNPC in Section III in the body text.

[24]The solutions for the above inequality also contains

$$v \leq \frac{-\theta - 4 - 2\sqrt{2\theta(1+\theta) + 4}}{2\theta^2}.$$

However, this inequality is never satisfied, since, from $\theta > 0$, it follows that the right-hand side of the inequality is always negative.