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Recovery of Steel Manufacturers in Urayasu, an Area Stricken by the Great East Japan Earthquake

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1. A new method of regional analysis

1.1. Purpose and prior work

On March 11, 2011, a large-scale earthquake struck the Tohoku region, causing major damage. This was The Great East Japan Earthquake. In the Kanto region, south of Tohoku, damage of a different kind occurred — liquefaction of the ground surface. Water flowed out from reclaimed land and caused major damage to buildings and other infrastructure.

Urayasu, a city in Chiba Prefecture, was hit hardest by this. The area is located at the deepest point of Tokyo Bay, with three quarters of the city being built on reclaimed land since the 1950s. Liquefaction caused many buildings to tilt, producing numerous cracks. The roads and infrastructure were subject to major damage, and the water mains for 35,000 households were stopped. In addition, 37,000 households had partial or fully suspended sewer lines, and 5,000 had no gas supply.[1]

Urayasu is noted as the site of Tokyo Disneyland and consists of three major economies. The first is the tourism industry as an offshoot of Tokyo Disneyland; the second is steel works, centered around the Urayasu steel industrial park; and the third is the local private-sector economy, which encompasses commercial areas. The Urayasu steel industry in particular is a major pillar supporting the economy of eastern Japan. The industrial park area manufactures semi-finished steel items for shipment to other operators. This paper seeks to analyze why the steel industrial park in Urayasu, despite being subject to liquefaction, was able to maintain increased production of semi-finished steel products and continue their supply in an unbroken fashion, contributing to the restoration of the Japanese economy after the disaster.

In order to achieve the above, we developed a total factor productivity ratchet theory.

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The authors previously developed the MAIDO economic model in Mizuno, K. et al (2016). This model was then combined with the generalized residual method developed by Katsuyuki Mizuno (1986) and an analysis performed. While a traditional measurement model used in total factor productivity assumes first order homogeneity of the production function, the generalized residual method replaces elasticity of scale (the order of the above) with $1/\gamma$ instead of 1. Where $1/\gamma = 1$, the constant returns can be seen; where $1/\gamma > 1$, the increasing returns to scale can be seen; where $1/\gamma < 1$, the decreasing returns to scale can be seen. The MAIDO model allows for measuring $1/\gamma$. Applying this measurement value to the generalized residual method allows for measuring the degree of returns to the scale of the steel industry in Urayasu. What we found was that the steel industry in Urayasu experiences the increasing returns to scale, and the increasing returns in turn promoted technological progress during recessionary periods, preventing the industry from sliding backwards, producing a ratchet effect. The new total factor productivity ratchet theory developed by the authors describes how the steel industry in Urayasu was able to rebuild a supply infrastructure for the stable provision of resources needed for the reconstruction of the Tohoku region.

1.2. Prior work

Prior work on the amount of damage to public facilities in Urayasu can be found in H. Ota, T. Adatai, M, Miamura, R. Niyama, and Y. Sato (2014). H. Ota et al developed a method of evaluating the losses caused by liquefaction damage to Urayasu. This highly intriguing piece of research calculates the amount of damage to public and educational facilities. However, this is a piece of policy-related research that is informed by architecture, so it does not perform an economic analysis of the impact to the private-sector economy of Urayasu.[2]

Total factor productivity here describes the rate of technological progress. Prior work measuring the rate of technological progress in regional economies includes H. Matuoka (2005). In that work, the rate of technological progress in Fukui Prefecture, Ishikawa Prefecture, and Osaka Prefecture was measured and a comparison of their economies performed. However, this involved the major restriction of assuming Cobb-Douglas first order homogeneity for the production function. In this paper, we treat elasticity of scale as $1/\gamma$, given that the aboves was not a flexible enough assumption to appropriately describe the real economy.

In the aforementioned Mizuno et al (2016), we developed the MAIDO model. One aspect of this model is its usefulness in demonstrating results, given that it allows for measuring data even where elasticity of scale is not 1. K. Mizuno et al (2016) used the MAIDO model to analyze the forestries sector and measure total factory productivity, obtaining a more accurate measure of total factor productivity in the Japanese forestries industry. We combined this form of industrial analysis with the theories of H. Theil (1980a, 1980b) to refine the MAIDO model and use it for analysis of regional economies. In the case of the Urayasu steel industry, total factor productivity for the region was measured in order to analyze conditions not under normal circumstances, but rather the reason the industry was able to quickly recover from the disaster.

2. Current conditions of the manufacturing industry in Urayasu

We focused on the manufacturing industry in Urayasu to determine the extent of The Great East Japan Earthquake (March 11, 2011) there. Of Urayasu's manufacturing sector, the steel industry has the highest value of shipped goods, followed by the ceramics industry, the metal industry, and the printing industries. Of these, we focused on the Urayasu steel works industrial park where many of the steel operators congregate.[3] Following construction of reclaimed land in part of offshore Urayasu in 1963, factories and other buildings were built in the area, creating an industrial park devoted to steel manufacturing. In 1979, a subsequent project to build reclaimed land offshore was completed; further steel manufacturers built facilities there, expanding the area of the industrial park.

There are 270 firms within the Urayasu industrial park, and 4,200 people working there (as of 2007). Large steel production firms produce their own steel, but they cannot use it in that state. The Urayasu steel park acts as a distribution and logistics area in which crude steel is then refined, warehoused, and distributed. For firms with demand for semi-finished steel products, having a centralized place for integrated distribution in the Urayasu park represents a major convenience. By way of analogy, the Urayasu steel park functions in the same way the Tsukiji fish market works for seafood, linking producers and vendors across the supply chain.

At these 270 plants and warehouses, 6M tons of steel are handled annually, with 6,000 trucks coming and going daily and making shipments predominantly to the Kanto region. The Urayasu steel industrial park supports not only the steel industry in Urayasu, but in Japan as a whole. In today's day and age, where procuring large volume of steel, as was once done, is impractical, this system has allowed for the purchase of smaller lots.

Fig. 1 describes the value of shipments of products in the Urayasu steel park and is based on a statistical census of industry by the Ministry of Economy, Trade, and Industry. The value of shipped products in the Urayasu steel industry dipped to 98.2B JPY in 2002, but then gradually recovered; in 2007, it was 105B JPY. However, following the 2008 global economic crisis, 2009 saw a decline to 80.3B JPY. In 2012, a year after The Great East Japan Earthquake, the figure was 89.3B JPY; in 2013, it was 71.5B JPY; in 2014, it was 81.9B JPY.

3. Measurement of elasticity of scale

3.1. Economic model

Herein, we explain the generalized residual method using the MAIDO model. Where ρ is total factor productivity (increasing rate) and Y is production volume, with K representing capital stock and L representing labour (number of employees), a generalized residual

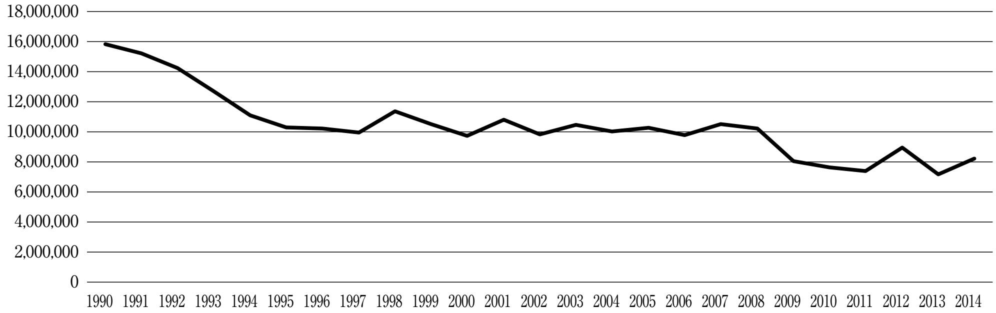

Fig. 1 Trends in the Urayasu steel industry (companies with four or more employees)

Source: compiled from annual Census of Manufacture by Municipality, the Ministry of Economy, Trade, and Industry. 2005 values.

method employing the MAIDO model is described using the following formula.[4]

$$\rho = \text{dln Y} - \frac{1}{\gamma}(f_K \text{dlnK} + f_L \text{dlnL}) \qquad (1)$$

f_K and f_L describe the share of capital and labour. This describes the proportion of costs against the whole of expenses.[5]

From the rate of increase in production volume is subtracted the weighted average of rate of increase in capital and labour (the Divisia quantity index). In other words, from growth in production volume, that which cannot be explained by capital and labour growth is treated as total factor productivity.

Herein, $1/\gamma$ corresponds to elasticity of scale. Where this value is 1, we have first order homogeneity. In formula (1), the second term on the right side of the function is the result after having multiplied elasticity of scale.

3.2. Features of this model and how calculations are performed

Above, we discussed an elasticity of scale of $1/\gamma$. This measurement method is called the MAIDO model and offers two methodologies. The first method, described in the aforementioned Mizuno et al (2016), employs a CES production function. The second technique, discussed herein, does employ a CES production function, but instead of estimating it directly uses its underlying properties instead. The latter employs H. Theil's system-wide approach.

Using the MAIDO model developed by the authors, this report aims to analyze the extent of activity of Urayasu's steel industry.

The system-wide approach is based on microeconomics. We believe this is the optimal theory to apply to a subject that falls precisely between the microeconomic scale of a local economy and a macroeconomic scale.

The system-wide approach used to analyze the steel industry in Urayasu is described using the following formula (2). Only the following formula need be used to estimate labour.[6]

$$f_L \mathrm{dln\,L} = \gamma\theta_L \,\mathrm{dln\,Y} + \pi_{LL} \,(\mathrm{dln\,p_L} - \mathrm{dln\,p_k}) \qquad (2)$$

θ_L : marginal share of labor (ratio of labor cost increase rate to cost increase rate)

π_{LL}: Slutsky coefficient parameter

p_L : labor price

p_K : capital price

An estimate of economic activity between 1991-2012 was performed for Urayasu's steel industry. Given that the parameters are nonlinear, the residuals assume normal distribution, and the maximum likelihood method was used.

$$f_L \mathrm{dln\,L} = 0.2780\mathrm{dln\,Y} - 0.0656 \,(\mathrm{dln\,p_L} - \mathrm{dln\,p_k})$$

In this case, elasticity of scale is as follows.[7]

$$\frac{1}{\gamma} = 1.8525$$

The CES production function yields a 1.8525 order homogeneity, with the slight increasing returns of scale. This is consistent with the Urayasu steel park functions being called the steel department.

Table 1 Maximum likelihood estimation

(Log likelihood = 45.2131; measured value = 22)

	Coefficient	Standard error	z-value	P-value	95% Conf. Interval	
dlnY	0.278	6301	4.41	0	0.1545	0.4015
dln p_L-dln p_K	−0.0656	0.1311	−0.5	0.617	−0.3226	0.1913

4. Using the MAIDO model to measure ratchet effects in the Urayasu steel industry

4.1. Measurement of total factor productivity

With elasticity of scale found, it is substituted into formula (1) to measure total factor productivity. First, the average value of total factor productivity in the Urayasu steel industry before The Great East Japan Earthquake, in 2010, was measured. The average between 1991 and 2010 was, in the case of elasticity of scale of 1.8525, 0.0022. This means that, in Urayasu's steel industry, total factor productivity increased by an annualized average of 0.2%. That being said, this is nearly zero, implying that there was almost no technological progress.[8]

Let us next look at total factor productivity in Urayasu's steel industry following The Great East Japan Earthquake of 2011. Total factor productivity in Urayasu's steel industry following The Great East Japan Earthquake as described in Table 2 is −16.93% in 2011, −10.96%

in 2012, −63.7% in 2013, and +17.32% in 2014. Over these four years, total factor productivity declined to an average of −0.0423.

Table 2 Total factor productivity in Urayasu's steel industry following The Great East Japan Earthquake

2011	−0.1693
2012	−0.1096
2013	−0.0637
2014	0.1732

The −16.93% figure seen in 2011 is likely largely owed to the effects of The Great East Japan Earthquake. There was major damage to facilities and infrastructure, and technological progress was forced to fall behind. The result was a 20% decline. As mentioned, liquefaction impaired the local infrastructure, putting a damper on the shipment and receipt of steel. In other words, this was not a time for technological innovation — quite the opposite. Following the breakdown of the social infrastructure, total factor productivity in Urayasu's steel industry declined.

Total factor productivity in 2012 was −10.96%. The reconstruction of Tohoku necessitated steel, which increased the total amount shipped out of Urayasu. While capital and labour increased, technological capacity itself did not function as intended. Amid decline in technological progress, the industry made efforts to still maximize production output.

In 2013, depressed demand for steel led to lower production volume, and technological progress for 2013 was down 6.37%. However, this production volume should have implied a greater decline in technological progress, but 2013 witnessed a total factor productivity ratchet effect. This will be explained in the next section.

A positive increase of 17.32% in 2014 was largely owed to a ratchet effect. In spite of the negative Divisia index (discussed later), since demand for steel increased, this drove technological progress, which in turn led to increased production output. The infrastructure also improved, and the difficulty of receiving and sending products greatly declined. Increased demand drove technological innovation, which allowed for the industry to successfully drive further production output.

4.2. Total factor productivity ratchet effect: 2013, 2014

A ratchet effect in the context of consumer theory applies when, in a recessionary economy, average consumption trends upward, thereby halting further recessionary effects. The ratchet effect we surmised here increases technological progress during an industry downturn and impedes its further decline. In terms of scale, in cases of slight increasing returns to scale (elasticity of scale of $1/\gamma > 1$), if the Divisia quantity index in parenthesis in the second part of the expression on the right side of formula (1) is a negative during a downturn, the larger elasticity of scale is, the more it impedes declines in total factor productivity.

Measuring Divisia quantity index for Urayasu's steel industry post-2011 yields the following.

Table 3 Divisia quantity index for Urayasu's steel industry

2011	0.0688
2012	0.1397
2013	−0.0481
2014	−0.0586

Using the Divisia quantity index, 2013 and 2014 posted a net negative. Looking at the statistical data, both years show a decline in tangible fixed assets and in workers. This is responsible for making the Divisia quantity index a negative. Decreasing returns to scale and constant returns to scale do not significantly improve total factor productivity. Because the condition of the steel industry in Urayasu is under the increasing returns to scale, the total factor productivity was boosted when the Divisia quantity index declined. In other words, a ratchet effect was at work in Urayasu's steel industry.

Total factor productivity for 2013 was a downswing of 6.37%; had elasticity of scale not been 1 or greater, total factor productivity would likely have been even lower. This implies a ratchet effect.

The growth seen in 2014 total factor productivity was a negative in terms of Divisia quantity index, but the overall outcome was still a positive change of 17.32%. The second part on the right side of the formula (1) is a positive, indicating the major growth in total factor productivity. This is nothing short of a total factor productivity ratchet effect.

A total factor productivity ratchet effect in Urayasu's steel industry enabled production increases in 2012 and 2014 following The Great East Japan Earthquake of 2011.

5. Summary

The model used in this paper theoretically demonstrates how Urayasu's steel industry, subject to major damage following The Great East Japan Earthquake, achieved growth in production output by securing technological progress through a total factor productivity ratchet effect. To what extent was there technological progress, then? Specifically, it involved the purchase of capital goods to produce items meeting demand for reconstruction following The Great East Japan Earthquake. This paper sought to uncover the causes behind reconstruction of Urayasu's steel industry, and our findings suggested that what was behind this was a total factor productivity ratchet effect based on the purchase of these capital goods.

A proverb in Japan talks about turning misfortune in fortune — ironically, The Great East Japan Earthquake was a turning point of innovation for Urayasu's steel industry. In this way, economic activity in Urayasu's steel industry was a major factor in restoring the economy not only of the Tohoku areas stricken by the disaster, but of Urayasu itself.

This brings the following caveat: once demand following the reconstruction leveled off, Urayasu's steel industry should have faced declined motivation to innovate. This analysis did not go so far as to assess the microeconomic effects of why that motivation was present. This calls for future work identifying why there was motivation to innovate and finding ways of maintaining said motivation. While formula (1) demonstrates a ratchet effect, technological progress in Urayasu's steel industry did not continue in periods of a recessionary economy.

The price of steel is currently sluggish under international competition. With demand for steel now leveling off, motivation cannot be produced using the same methods as before. A future issue will be exploring how to maintain the motivation to achieve technological progress and continue increasing production volume.

6. Supplementary data

1. Data on production values, capital stock, and labour in the Urayasu steel industry was obtained from the Ministry of Economy, Trade, and Industry's Census of Manufacture.
   Ministry of Economy, Trade and, Industry, "Census of Manufacture 2014".
   1990-2014 data
   Production: steel industry
      Total value of steel product shipments　　Units: 10,000 JPY
      Value of manufactured goods shipments
   Capital stock: steel industry
      Tangible fixed assets (thirty or more employees)　Units: 10,000 JPY
2. Given that there was an explicit error value in the statistics, they were corrected. The years 2001, 2002, 2005, and 2006. One year was double, and then suddenly declined by half. The average before and after was taken and modified accordingly.
      Value of tangible fixed assets
   (Enterprises with 30 or more employees)
   Labour: labour
      Employees (steel industry)　　Units: people
      Number of persons employed
3. The value of L represents the number of workers multiplied by the annual working hours (2013 = 1,750 hours).
   Capital price: capital service price

2015 JIP data (Institute of Economic Research, Hitotsubashi University web site. http://www.ier.hit-u.ac.jp/Japanese/databases/index.html#10 Last checked on 7/26/2017)

In terms of the steel industry, the nominal capital service price* real capital stock (units: 1M JPY) was divided by real capital stock and the nominal capital service price made real using a private sector investment deflator (2005 basis). With respect to 2013 and 2014, since there is no JIP data, regression was performed against 1991-2012 where real capital service price = a+b real capital stock, with an estimate of the real capital service price for those years computed.

Cost of labour: wages

Cash salary (recalculated per person)

Source: Ministry of Economy, Trade, and Industry -- Census of Manufacture by Municipality

4. In terms of the value of tangible fixed assets, the Census of Manufacture by Municipality describes this as the total value for enterprises with ten or more employees for 1990-2000, and thirty or more employees for 2001-2014, respectively. However, the Census of Manufacture by Municipality only describe the total value for enterprises with ten or more employees for the years 2005 and 2011, so the value for enterprises with thirty or more employees for 2005 was estimated using the average of the years 2004 and 2006. The proportion for enterprises with ten or more employees for 2005 and the estimate for enterprises with thirty or more employees was 0.4455, and this was applied to the tangible fixed asset amount for 2011.

Notes

1 Urayasu City web page: Urayasu Damage Archive. Last accessed on 8/12/ http://urayasu-shinsai-archive.city.urayasu.lg.jp/special/page_02/

2 Given the constraints of space, we have not mentioned the details of other research, but Masamitsu Miyamura, Hiroshi Ota, et al have conducted several pieces of research on liquefaction damage to Urayasu.

3 Please refer to pp. 77-96 in Katsuyuki Mizuno (2007) for details on the park.

4 Model taken from pp. 134-135 of K. Mizuno, T. Doi, J, Omata, H. Ando, and G, Igusa (2016). The basis of this model was developed by Mizuno, K. 1986 and Mizuno, K. 1992 based on Theil, H. 1980.

5 $$f_K = \frac{p_k K}{p_k K + p_L L}$$

$$f_L = \frac{p_L L}{p_k K + p_L L}$$

6 Applying a Slutsky restriction to the consumption model (3.6) used in Theil, H. (1980b). This equation describes the corresponding productivity.

7 This formula yields

$\gamma\theta_L = 0.2780$

Using a CES production function yields $f_L = \theta_L$. The average value for f_L is 0.5150. Using that value in turn yields

$$\gamma = .0.5398$$

8 Here, total factor productivity is regarded as the technological progress rate, but not all are the technological progress rates. Interpret total factor productivity as a measure of technological progress.

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