Bank of Japan Review

2011-E-4

The Impact of the Earthquake on the Output Gap and Prices

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May 2011

The earthquake that struck Japan in March 2011 has reduced the supply capacity of the economy, which works in the direction of tightening the output gap. At the same time, however, if weak household and corporate sentiment lead to a decline in aggregate demand, this will work in the direction of increasing the slack in the economy. Moreover, developments in supply and demand conditions will differ for different goods and services. The impact of the earthquake on the output gap and prices, therefore, is not straightforward. Moreover, for these reasons, caution is needed when interpreting the results of production function estimates of the output gap. However, as long as medium- to long-term inflation expectations remain stable, temporary changes in the output gap due to the earthquake will have little effect on general prices in the economy as a whole.

Introduction

The Great East Japan Earthquake on March 11th caused devastating damage in Japan. Economic activity in Japan was severely constrained as a result of supply side problems caused by damage to production facilities, disruption to supply chains, and power shortages. In addition, there is concern that the earthquake may put downward pressure on aggregate demand through a variety of channels such as a deterioration in business and household sentiment. This review will discuss the impact of the earthquake on the output gap and prices.

When there is a negative demand-side shock – such as a deceleration in overseas economies or a decline in the effect of demand-boosting policy measures – aggregate demand decreases (Chart 1). As a result, slack in the economy and downward pressure on prices arise. Since the production of goods and services requires capital and labor, a negative demand shock also results in a decline in derived demand for capital goods and labor. This, in turn, gives rise to downward pressure on the price of capital and on wages (Chart 2).

In contrast with the scenario just described, however, the earthquake brought about a supply-side shock. The capital stock of firms was damaged and production at some firms was severely hampered. Production at firms which were not directly affected

Chart 1 A Negative Demand Shock

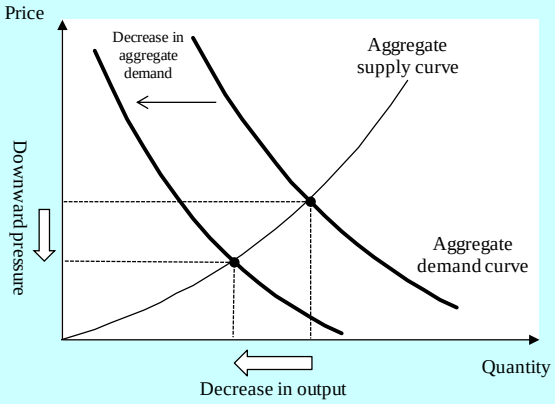
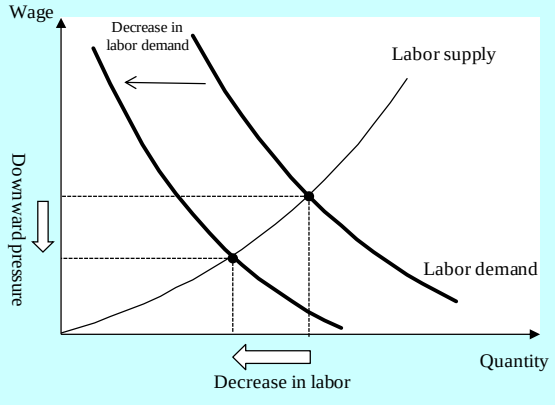


Chart 2 Labor Market



by the earthquake was also hampered as a result of power shortages. In addition, even production in areas that remained unaffected by the earthquake and by power shortages was negatively affected due to the disruption to supply chains. A representative example is the automobile industry: many car makers have faced difficulties in procuring parts and components due to supply chain disruptions. Thus, the earthquake has been hampering production from the supply side through a variety of channels. Furthermore, the earthquake disaster, the nuclear accident it triggered, and the power shortages seem to have resulted in a decline in firm and household expenditure through a deterioration in sentiment. How these factors will affect supply and demand conditions in the various markets for goods and services and in the economy as a whole is a complex matter. Moreover, how the changes in supply and demand conditions will affect general prices is highly uncertain.

Against this background, the following sections examine the impact of the earthquake on the output gap using a simple aggregate demand and supply curve analysis; consider the impact of the earthquake using production function analysis employed for the estimation of the output gap; and, finally, look at how the changes in the output gap due to the earthquake will affect general prices.

Demand and Supply Curve Analysis

When a natural disaster such as an earthquake results in the loss of human life and capital stock, this gives rise to a decline in supply capacity. However, if only a relatively limited area is hit by the natural disaster, such a decline is unlikely to bring about a large scale decline in the supply capacity of the economy as a whole. This was true for the case of the Great Hanshin-Awaji Earthquake. In contrast, following the Great East Japan Earthquake, Japan's economy as a whole faces serious supply-side constraints. First, firms' and households' activities are severely constrained owing to the power shortages. Second, the automobile and information technology industries are facing large-scale supply chain disruptions due to severe damage at firms providing parts and materials that cannot be easily sourced from elsewhere.

Let us examine this situation using aggregate demand and supply curves. When there is a negative supply shock – such as power shortages or supply chain disruptions – this will result in a shift of the aggregate supply curve to the left (Chart 3). In this case, the output of goods decreases, supply and demand conditions tighten, and there is upward pressure on prices (Chart 4).[1] Once supply constraints such as power shortages and supply chain disruptions are resolved, the supply curve will return to its original position and the balance of supply and demand will revert to its original level.

Chart 3 A Supply Shock

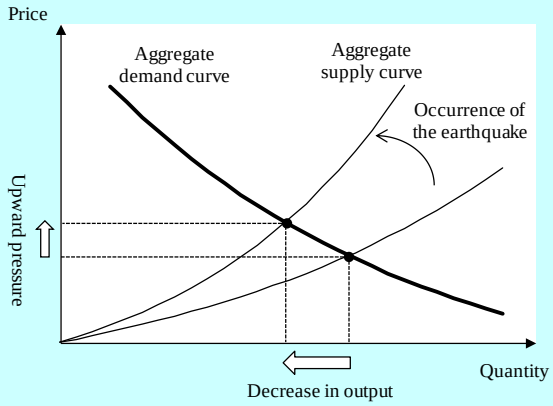
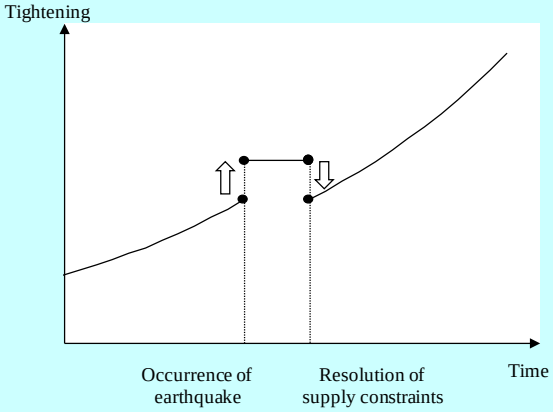


Chart 4 Output Gap (1)



The earthquake is also likely to have led to a deterioration in business and household sentiment due to heightened uncertainty, resulting in a worsening in the income environment owing to the constraints on production activity and, ultimately, in a decline in demand (Chart 5). Further, aggregate demand may potentially also decline as a result of shortages of particular parts and materials, which may force final goods producers to reduce output, leading to a decline

in demand for other goods. In these cases, the output of goods declines further and slack in the economy increases (Chart 6). Moreover, if there are fears that supply-side constraints may be prolonged, expectations of future income in the medium- to long-term may decline and current spending activity may contract.

The considerations above mean that whether supply and demand conditions will loosen or tighten depends on the extent of the shifts in the aggregate demand and supply curves.

Chart 5 Shifts in the Demand and Supply Curves

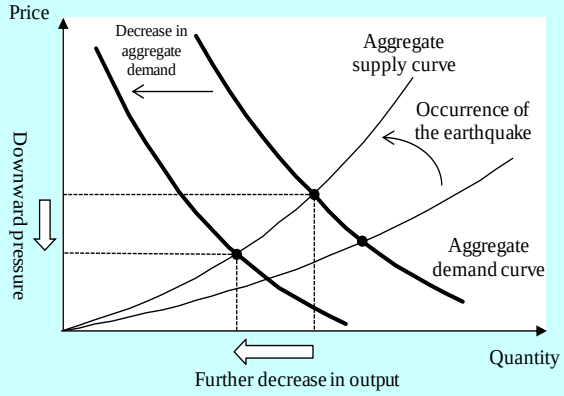
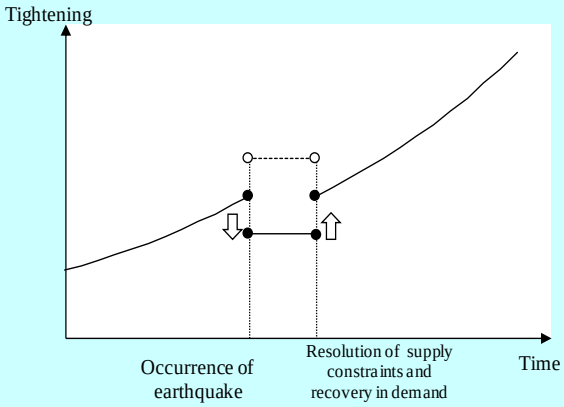
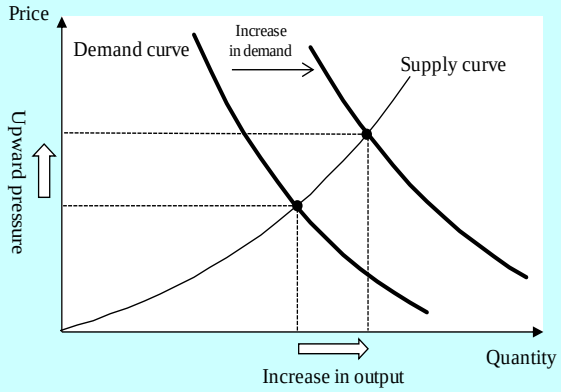


Chart 6 Output Gap (2)



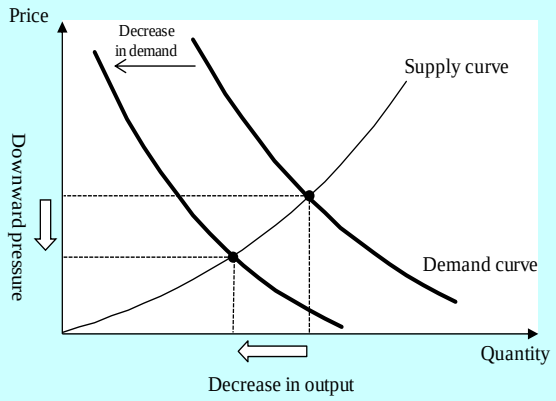
Moreover, it should be noted that developments in the markets for individual goods and services can differ from those in the economy overall. Goods which face serious supply constraints are likely to see a decrease in output and upward pressure on prices. On the other hand, certain necessities, such as specific food items and batteries, may experience a significant increase in demand due to the earthquake, but face no supply-side problems. In this case, since the demand curve shifts to the right, output of such goods is likely to increase and upward pressure on prices likely to arise (Chart 7).

Chart 7 An Increase in Demand



Goods and services such as apparel, travel, and eating out, are likely to see a decline in demand due to the deterioration in consumer sentiment. In this case, the supply curve remains unchanged, while the demand curve shirts to the left (Chart 8). Output declines and there is downward pressure on prices.

Chart 8 A Decline in Demand



However, these developments in the prices of individual goods and services are ultimately changes in relative prices and do not necessarily indicate developments in aggregate prices.

Production Function Analysis

Let us now consider this analysis based on demand and supply curves in terms of the kind of production function which is typically used for the estimation of the output gap at the macro level. The production function approach usually assumes a Cobb-Douglas

production function with two types of input – capital and labor – of the following form:

$$Y = AK^{\alpha}L^{1-\alpha},$$

where Y is output, A is total factor productivity (TFP), K is capital stock, L is labor input, and α is the capital share. Using the above equation, potential output Y^* is calculated using the potential capital input K^* and the potential labor input L^*. The output gap ($=(Y-Y^*)/Y^*$) is the deviation of the actual output Y from the potential output Y^*, which reflects supply side conditions. As shown in Charts 1 and 2, the actual output (Y) is determined by the demand-side factors in a normal business cycle. Based on the Cobb-Douglas production function shown above, the output gap can be expressed as a weighted average of capital and labor utilization rates:

$$\alpha\left(\frac{K-K^*}{K^*}\right)+(1-\alpha)\left(\frac{L-L^*}{L^*}\right).$$

The Research and Statistics Department of the Bank of Japan estimates the output gap using the above relationship and capital and labor utilization rates.[2]

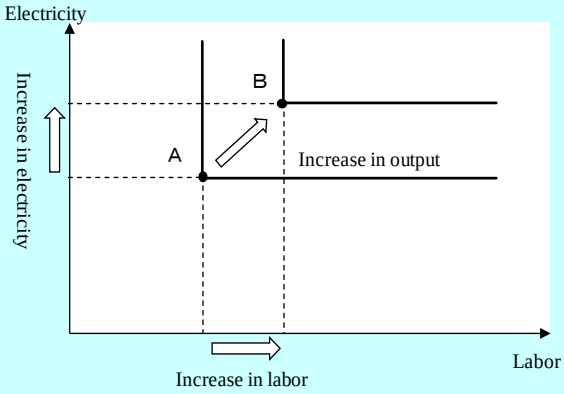
To examine the impact of the earthquake, several extensions of this production function are needed. The earthquake caused not only damage to production facilities, but also power shortages and supply chain disruptions. These all contribute to the shift of the aggregate supply curve. Therefore, apart from the capital stock and labor input, it is necessary to explicitly take electricity supply and parts and components into consideration as production factors. In addition, at least in the short run, it is impossible to find substitutes for some key components, meaning that there is no substitution between factors of production. Taking this into account, it is more appropriate to use a Leontief production function of the following form:

$$Y = \min[aK, bL, cE, dP],$$

where E is electricity input, P is parts inputs, and a, b, c, and d represent the units of output per unit of input.

For illustration, Chart 9 depicts the isoquants of a simple Leontief production function with two factors of production, labor and electricity. In a Leontief production function, there is no substitution between factors of production and the isoquants are L-shaped. This means that it is impossible to increase output by raising labor input if there are electricity shortages. A move up and to the right in the chart represents an increase in output and a move down and to the left represents a decrease in output.

Chart 9 Leontief Production Function

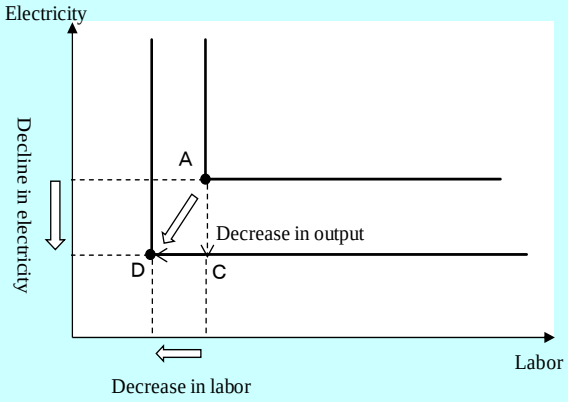


Considering now the impact of the earthquake, this means that potential output Y^* will decline to the level consistent with the input of the factor that is the most constrained as a result of the disaster. In the preceding section, it was suggested that the damage to production facilities, power shortages, and supply chain disruptions cause the aggregate supply curve to shift to the left. In terms of the production function approach, this can be interpreted as a decline in the available capital stock K^*, the available electricity E^*, and the available parts P^*. Potential output will decline to the level consistent with the most constrained factor of production, aK^*, cE^*, or dP^*. Suppose the power shortages represent the most severe input constraint. Then, as shown in Chart 10, potential output declines as the available electricity falls from A to C. At the same time, the required labor input for production also falls, from C to D. Thus, in this scenario, what determines output is not labor input, but the available amount of electricity.

Using this framework to consider the impact of the earthquake on the output gap, a number of points can be made. First, the constraining factors in production can change over time. For instance, at present, the automobile industry cannot produce cars at full capacity due to the shortage of certain critical

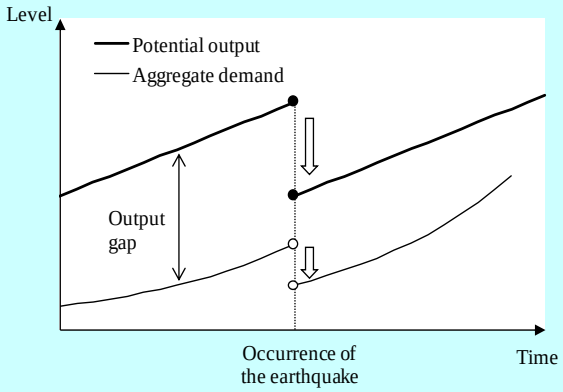
parts and components. This means that the shortage of critical parts due to supply chain disruptions is the binding factor for production and therefore the potential output level is reduced. However, while it is expected that progress will be made in the reconfiguration of supply chains, power supply shortages could become a new binding constraint on production in the summer.

Chart 10 Impact of Electricity Shortage



Second, as described in the previous section (Charts 5 and 6), aggregate demand may decline due to a deterioration in sentiment, which would lead to a widening of the output gap. This is shown in Chart 11. As seen in the previous section, whether the output gap will shrink or widen depends on what falls more, potential output or aggregate demand.

Chart 11 Potential Output and Aggregate Demand



Third, if the output gap is calculated only as a weighted average of capital and labor utilization rates, this may exaggerate the degree of slack when compared with the output gap calculated taking into account the availability of electricity and critical parts. As shown in Chart 10, utilization of labor will decline from C to D if there are constraints on the supply of electricity. In this case, capital utilization will also decline. Similarly, the utilization rates of capital and labor will decline if, instead of electricity shortages, shortages of critical parts act as a constraint. Thus, if the output gap is calculated simply as the weighted average of capital and labor utilization rates, the estimated output gap could exaggerate the degree of slack in the economy.

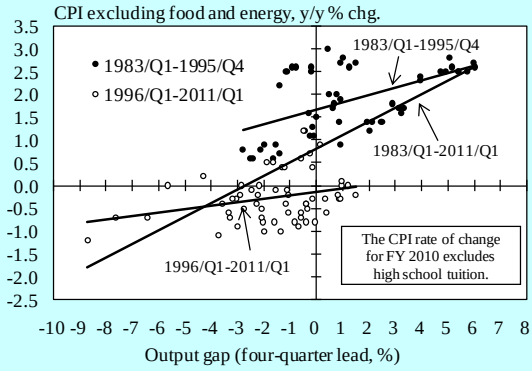
Fourth, a Leontief production function only describes the situation in the short run. Power shortages, for example, can be mitigated through additional generating capacity such as the introduction of in-house power generation facilities. In addition, critical parts and components, which initially were thought to be impossible to substitute, could be replaced by other parts through product and process modifications. Thus, substitutability among production inputs will increase as time goes by. Consequently, from a longer-term perspective, it is more appropriate to use a Cobb-Douglas production function, which allows for substitutability among factors of production, than a Leontief production function.[3] In this case, the decline in potential output will be smaller to the extent that factors of production can be substituted for each other.

Implications for Prices

The fourth point above is particularly important when considering the impact of the output gap on general prices. The relationship between the output gap and inflation, the so-called Phillips curve (Chart 12), is typically estimated using the Cobb-Douglas production function. Moreover, the actual values for the output gap and the inflation rate for each period often deviate from the Phillips curve. This suggests that, when looking at the relationship with inflation, it is more appropriate to measure the output gap in terms of the kind of time span implied when using a Cobb Douglas production function. Furthermore, actual combinations of the output gap and the inflation rate often diverge considerably from the Phillips curve, so that trend movements are more meaningful than the

changes in each period.

Chart 12 Phillips Curve



Sources: "Consumer Price Index," Ministry of Internal Affairs and Communications; "National Accounts," Cabinet Office.

In practice, it seems likely that even if the output gap fluctuates in the short run due to the earthquake, prices will remain unchanged as long as medium- to long-term inflation expectations remain stable. Although the prices of some items, such as plywood, are increasing due to shortages caused by the earthquake, the prices of most items, including some food items facing considerable shortages, have held steady at the retail level (Table 1). The likely reason is that firms consider the supply shortages to be only temporary. Thus, if they were to raise prices to increase short-term profits, this would probably greatly damage their reputation and they would lose customers in the long run. Taking this line of reasoning into account, firms' price setting behavior – that is, not to raise prices even when there are shortages – is entirely rational.[4]

Table 1 The CPI Inflation Around the Time of the Earthquake

y/y % chg.

	CPI excluding food & energy and high school tuition					
		Agricultural & aquatic products	Food products	Clothes	Durable goods	Other goods
10/10	-0.2	-1.1	-1.8	0.6	-6.4	0.6
11	-0.2	-1.7	-1.6	0.8	-6.0	0.7
12	-0.1	-1.2	-1.8	0.4	-5.4	1.1
11/1	0.1	0.0	-1.5	2.3	-4.5	0.9
2	-0.1	-0.9	-1.6	3.1	-5.7	0.9
3	0.0	-0.8	-1.7	4.1	-5.8	0.9
4	0.2	0.9	-0.5	1.0	-5.6	0.4

Note: The table shows the year-on-year rate of change in the CPI for Tokyo.

Source: "Consumer Price Index," Ministry of Internal Affairs and Communications.

However, there is a risk that general prices may go up if supply-side constraints such as power shortages and supply chain disruptions continue for a prolonged period. On the other hand, prolonged constraints on supply capacity may push down firms' and households' long-term income expectations, in which case there may be a larger decline in aggregate demand, putting downward pressure on general prices and wages.

Conclusion

Supply-side constraints due to the earthquake, such as damage to production facilities, supply chain disruptions, and power shortages, work in the direction of tightening the output gap. At the same time, however, the earthquake may work in the direction of decreasing aggregate demand if business and household sentiment and income deteriorate as a result of constraints on production activity. In this case, there will be downward pressure on aggregate demand and slack in the economy will increase. Whether the output gap will increase or decrease depends on the extent of the shifts in the supply and the demand curves.

Furthermore, developments in the markets for individual goods and services may differ from those for the economy as a whole. When examining such developments using production functions employed for the estimation of the output gap, it is necessary to take into account that (a) what factors act as a constraint can change over time; (b) aggregate demand can change over time; (c) estimates of the degree of slack in the economy can differ depending on the production function and data used (i.e., estimates based on a Cobb-Douglas production function with capital and labor utilization rates may overestimate the degree of slack in the economy); (d) the shape of the production function can change over time.

Therefore, while there are various possibilities regarding the way the earthquake may affect macro-economic supply and demand conditions, what is important when considering the implications for prices is the relationship between the

macro-economic output gap and inflation in the longer term. Even if there are temporary fluctuations in the output gap as a result of the earthquake, prices are likely to remain unaffected as long as medium- to long-term inflation expectations remain stable. However, there may be both upside and downside risks for general prices if the supply-side constraints persist for a prolonged period.

[1] In Charts 4, 6, and 11, it is assumed that supply and demand conditions tighten over time. For details on the actual outlook for the Japanese economy and the output gap, refer to the "Outlook for Economic Activity and Prices (Outlook Report April 2011)."

[2] Details of the estimation method of the output gap by the Bank of Japan are described in "The New Estimates of Output Gap and Potential Growth Rate," Bank of Japan Review Series 06-E-3, May 2006.

[3] For more on how the production function differs depending on the time frame, see Fukunaga and Osada, "Measuring Energy-Saving Technological Change in Japan," Bank of Japan Working Paper 09-E-5, November 2009.

[4] This is in line with New Keynesian economics, which argues that changes in the output gap have only a limited impact on prices when inflation expectations are stable and nominal prices are sticky.

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