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# Macroeconomic policy coordination between Japanese central and local governments\*

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## **Abstract**

It is commonly believed that public investments play a central role in Japan's discretionary fiscal policies, but the majority is implemented by local governments. After distinguishing between public investment by the central government and that by local governments, this paper utilizes wavelet techniques to examine macroeconomic policy coordination between Japanese central and local governments. We demonstrate that local government investments fail to coordinate with central government investments during the last two decades, and such a coordination failure is a one-time phenomenon in nearly a half-century. In this period, local government investments exhibit no countercyclical behavior to business cycles, which is contributory to the ineffectiveness of fiscal stimulus that is pointed out by our predecessors.

*Keywords:* Public investment; Wavelet; Central government; Local government

*JEL classification:* E32, E62

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# 1 Introduction

The Japanese government has been pursuing public investment projects as the primary stimulus means for macroeconomic stabilization. To date, a large literature has studied the effects of Japanese public investment policy. Previous works take particular note of the period after the burst of the bubble economy in the early 1990s. Bayoumi (2001), Ihori et al. (2003), Brückner and Tuladhar (2010), and many others have pointed out that the effects of fiscal policy were dampened in the 1990s.

In the literature, excluding the recent works by Miyazaki (2008, 2009), there has been no empirical work in which central and local government investments have been distinguished separately.<sup>1</sup> As emphasized in Miyazaki (2008, 2009), most public investments have been implemented by local governments, and it seems important to assess separately the effects of central and local government investments. Based on vector autoregression (VAR) models, he shows that while central government investments stimulate business cycles, local government investments have no positive impact on them.

Nonetheless, there still remain some issues to be clarified. Miyazaki (2008, 2009) highlights the impulse response functions of business cycles to central and local governments' investments. However, the relationship between central and local government investments is not quantitatively investigated, especially at business cycle frequencies that are relevant to fiscal policy for macroeconomic stabilization. From a fiscal stimulus perspective, a key issue is whether local government investment operates at the same time as central government investment at business cycle frequencies. In other words, it matters whether not only central government but also local government behaves counter-cyclically according to Keynesian demand management principles.

In addition, the sample periods of those works may be unreasonable. Although Miyazaki (2008) and Miyazaki (2009) use somewhat different observations from January 1990 to March 2000 and from January 1986 to December 2001, respectively, the reasons and interpretation are less obvious. Hence, the above results may change under other observations, and some plausible interpretations should be provided.

Further, an evaluation of fiscal policies during recent years is yet to be conducted—and it is highly likely that the Great Recession in 2008 brought about drastic structural changes, even in the Japanese economy. Until the dramatic worldwide slowdown, countercyclical discretionary policy was considered to be an inadvisable

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<sup>1</sup>There exist two levels of local government in Japan, i.e., prefectural and municipal governments. What we call “local government” in this paper includes both of them.

stimulus measure among many macroeconomists, as stated in Eichenbaum (1997), Taylor (2000), Feldstein (2002), and others. However, after the Great Recession occurred, some economists began to recommend active fiscal policy for rejuvenating the sharply declined economy, and temporary stimulus packages were instituted in Japan. The extent to which the local governments work in tandem with the central government in these recent circumstances is also interesting.

In this paper, we seek to extend the earlier approaches in two ways. First, we prolong the sample period as long as possible within the range of available data by allowing for time-varying relationships and multiple structural breaks without prior information. The existing research targets wide-ranging periods, but our observations are limited by nothing at all. Second, in order to take a close look at time series interactions between variables from the short-run perspective, we pay special attention to the business cycle frequencies by decomposing the variables into different periodic cycles. There is no reason to assume a priori that economic variables exhibit the same behavior across all frequencies.

To this end, we take a modern wavelet approach to examine the above issues. In the context of time series analysis so far, some researchers have resorted to time domain analysis such as some VAR and time-varying parameter vector autoregressive (TVP-VAR) models (e.g., Primiceri, 2005), and others to the frequency domain analysis such as the Fourier analysis and band-pass filters (e.g., Baxter and King, 1999; Christiano and Fitzgerald, 2003).<sup>2</sup> A TVP-VAR model seems useful in capturing the changing relationship between variables over time, but we are unable to extract the information of a particular frequency; band-pass filters can disentangle some time series into various periodic components, but they provide no information about the changing dynamics of each frequency component. On the other hand, as will be seen later, the wavelet analysis enables us to investigate simultaneously how variables are linked at various frequencies and how the relationship evolves over time. Recently, because of such usefulness, application of the wavelet method to economic analyses has grown at a rapid clip (e.g., Aguiar–Conraria et al., 2012; Caraianni, 2012; Rua, 2012).<sup>3</sup>

Our wavelet results indicate that the nexus between central and local government investments changes quickly over time, even within a typical business cycle frequency range. With regard to fiscal stimulus, it is shown that local government investments behave quite differently from central government investments during the lost two

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<sup>2</sup>For example, Ihori et al. (2003) and Ahmed et al. (2004) use both VAR and frequency domain techniques in a mutually complementary manner.

<sup>3</sup>See Yogo (2008) for a comparison between a band-pass filter and a wavelet filter for GDP data. For more details of wavelet analysis in economic time series, see also Aguiar–Conraria and Soares (2013).

decades. In particular, their association is weaker at the business cycle frequencies after the burst of the bubble economy in the early 1990s and before the onset of the Great Recession precipitated by the Lehman Brothers collapse in 2008. As a result, central government investments are countercyclical to business cycles, while local government investments have no connection to business cycles.

The view obtained from this analysis supports the evidence amassed by Bayoumi (2001), Ihuri et al. (2003), Brückner and Tuladhar (2010), and others, and it gives an interpretation to previous findings that the effects of fiscal policy on the macroeconomy have weakened in the lost decade. Furthermore, our consequences for local public sector investments are consistent with Miyazaki (2008, 2009) and shed light on the reason why local government investments have been ineffective in offsetting business cycles. In other words, to the extent that the majority of the lost two decades are concerned, local government investments have not been implemented with adequate timing to smooth business fluctuations in the first place.

The rest of the paper is organized as follows. In Section 2 we provide a brief overview of the wavelet methodology, including the wavelet transform, the wavelet power spectrum, the cross wavelet transform, the wavelet coherency, and the phase difference. Through the use of such wavelet measures, empirical results are presented and discussed in Section 3. Section 4 concludes.

## 2 The wavelet analysis

In line with recent studies applying the wavelet analysis to economics—such as Aguiar–Conraria et al. (2012), Caraianni (2012), Rua (2012) and others—we consider the continuous wavelet transform. That is, given a time series  $x(t)$ , its continuous wavelet transform for a mother wavelet  $\psi$  is expressed as follows:

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t) \tilde{\psi}^* \left( \frac{t - \tau}{s} \right) dt, \quad s, \tau \in \mathbf{R}, s \neq 0, \quad (1)$$

where

$$\tilde{\psi}_{\tau, s}(t) = \frac{1}{\sqrt{|s|}} \psi \left( \frac{t - \tau}{s} \right), \quad (2)$$

$s$  is the scaling factor that determines the length of the wavelet,  $\tau$  is the translation parameter that represents its location, and the asterisk denotes complex conjugation.

If we consider the most commonly used mother wavelet, the Morlet wavelet,

which is given by

$$\begin{aligned}\psi_{\omega_0}(t) &= \pi^{-1/4} \left( e^{i\omega_0 t} - e^{-\omega_0^2/2} \right) e^{-t^2/2} \\ &\simeq \pi^{-1/4} e^{i\omega_0 t} e^{-t^2/2} \quad \text{for } \omega_0 \geq 5,\end{aligned}$$

then it is easy to see the relationship between frequencies  $f$  and the scaling factor  $s$  such that  $f \simeq 1/s$  under the condition  $\omega_0 = 6 \simeq 2\pi$ . Hence, we assume the Morlet wavelet and  $\omega_0 = 6$  as in Aguiar–Conraria et al. (2012).

The amplitude of the wavelet transform provides a useful tool for measuring the contribution to the variance of the series  $x(t)$  around each time and frequency. That is, the wavelet power spectrum is given by

$$WPS_x(\tau, s) = |W_x(\tau, s)|^2. \quad (3)$$

Unlike the classic power spectrum on the basis of the Fourier transform,  $WPS_x(\tau, s)$  indicates how the strength of the time series  $x(t)$  is distributed not only in the frequency domain but also in the time domain.

For the purpose of examining the relationship between two time series (denoted by  $x(t)$  and  $y(t)$ , respectively) of interest, we employ the cross wavelet transform:

$$W_{xy}(\tau, s) = W_x(\tau, s)W_y^*(\tau, s). \quad (4)$$

This complex number gives us two useful pieces of information.

First, on the basis of the amplitude, one can compute the wavelet coherency, which represents the normalized covariance. The wavelet coherency between  $x(t)$  and  $y(t)$  is given by:

$$R_{xy}(\tau, s) = \frac{|S(W_{xy}(\tau, s))|}{\sqrt{S(|W_{xx}(\tau, s)|)S(|W_{yy}(\tau, s)|)}}, \quad (5)$$

where  $S$  is a smoothing operator in time and frequencies. The wavelet coherency is normalized by the power spectrum of the two time series and measures the strength of the relationship between  $x$  and  $y$  at each time and frequency. It should be noted that  $R_{xy}(\tau, s)$  provides no information about the phase, because the numerator of the wavelet coherency is expressed as the absolute value of the cross wavelet transform.

Second, on the basis of the argument  $\phi_{xy} \in [-\pi, \pi]$ , one can also compute the phase difference, which is given by the following expression:

$$\phi_{xy}(\tau, s) = \tan^{-1} \left( \frac{\text{Im}(W_{xy}(\tau, s))}{\text{Re}(W_{xy}(\tau, s))} \right), \quad (6)$$

where  $\text{Re}(W_{xy})$  and  $\text{Im}(W_{xy})$  denote real part and imaginary part of the cross

wavelet  $W_{xy}$ , respectively. The meanings of  $\phi_{xy}$ , as stated in Aguiar–Conraria et al. (2012), are summarized as follows. When  $\phi_{xy} \in (-\pi/2, \pi/2)$ ,  $x$  and  $y$  move in phase. In particular, if  $\phi_{xy} = 0$ , then  $x$  and  $y$  move exactly together. On the other hand, when  $\phi_{xy} \in (\pi/2, \pi]$  or  $\phi_{xy} \in [-\pi, -\pi/2)$ ,  $x$  and  $y$  move out of phase.

At this point, we further explain the interpretation of  $\phi_{xy}$  in the present context. To see this, we now suppose that  $x$  is central government investment and  $y$  is local government investment. If central and local governments increase or decrease investment in exactly the same timing, then the instantaneous time lag between the two series cannot be observed (i.e.,  $\phi_{xy} = 0$ ). Thus, if they act cooperatively in fiscal stimulus, we would expect that  $\phi_{xy}$  is in the vicinity of zero at business cycle frequencies. By contrast, if they behave in an uncoordinated manner, we would find that  $\phi_{xy}$  deviates from zero significantly.

We next suppose that  $x$  is public investment by central or local governments and  $y$  is a certain business index. If public investment is countercyclical to business cycles according to Keynesian demand management principles, then they are out of phase at business cycle frequencies and  $\phi_{xy}$  is between  $\pi/2$  and  $\pi$  or between  $-\pi$  and  $-\pi/2$ . Conversely, if public investment is procyclical, then they are in phase and  $\phi_{xy}$  is between  $-\pi/2$  and  $\pi/2$ .

### 3 Empirical characterization

This section proceeds with the outcomes of the wavelet tools just described. When calculating the wavelet measures, we used ASToolbox by Luis Aguiar–Conraria and Maria Joana Soares.

#### 3.1 Data

We use monthly observations spanning the period from May 1969 to March 2013. Following Miyazaki (2008), public investments are the value of construction orders received, which is taken from the Ministry of Land, Infrastructure, Transport and Tourism. In order to examine the correlations between business cycles and public investments, as in Miyazaki (2008), we use two primary variables of macroeconomic business conditions: industrial production, and effective job offer rate (excluding new school graduates). One reason for choosing these two variables is that both series are adopted as a coincident index in the Indexes of Business Conditions by the Cabinet Office for the Government of Japan. The Index of industrial production is obtained from the website of the Ministry of Economy, Trade, and Industry, and effective job offer rate is gathered from the website of the Ministry of Health, Labor,

and Welfare. All the series are seasonally adjusted, and monthly growth rates are used.

## 3.2 Results

Before proceeding to the wavelet results, we discuss a preliminary attempt to undertake a comparison between central and local government investments over business cycles. Figure 1 plots their business cycle components by using an approximate band-pass filter developed by Christiano and Fitzgerald (2003). We notice from this figure that, until about the collapse of the bubble economy in the early 1990s, the business cycle components of central and local government investments move with the same phase and they move counter-cyclically according to Keynesian demand management principles.<sup>4</sup> On the other hand, during the lost two decades from the early 1990s to around the Great Recession in 2008, they move out of phase. It is worth noting that, while central government investments are countercyclical, local government investments are procyclical in this period. Not surprisingly, after that, they keep in phase with each other and exhibit countercyclical behavior again, plausibly due to the view that local governments coordinate again with central government for the purpose of recovering from the Great Recession as soon as possible. To complement the ocular evidence shown in Figure 1, the related correlation coefficients are reported in Appendix A.

To understand the changing dynamics in more detail, in what follows, we extend our analysis to the wavelet framework. As a starting point, concerning basic properties of the time series, Figure 2 presents the wavelet power spectrum for central and local government investments. By drawing a comparison between Panels A and B of Figure 2, we observe different characteristics between central and local government investments, although there is not much difference either over time or across frequencies in these two series. Overall, central government investments have relatively high power at business cycle frequencies and at high frequencies. On the other hand, local government investments have relatively high power at low frequencies rather than business cycle frequencies and even higher power at high frequencies. These outcomes illustrate the differences between central and local government behaviors,

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<sup>4</sup>In the present analysis, the Japanese business cycles refer to the “date of business cycles,” which is determined by the Cabinet Office for the Government of Japan, because it is the most common definition of business cycles in Japan. According to this definition, the range of the Japanese business cycle is approximately 2.5–7 years within our sample period. Throughout the paper, therefore, we assume 2.5–7 years as a benchmark cycle of the Japanese business cycles. Incidentally, the band-pass results are roughly similar even when using other ranges for the business cycle frequencies, e.g., cycles of 1.5–8 years (as in Baxter and King, 1999) and 2–4 years (as in Sargent, 1979).



and we interpret them as evidence that, compared with local government, central government's decision-making is prone to being affected by business fluctuations.

We now turn to the wavelet results of the relationship between central and local government investments. Figure 3 shows the wavelet coherency between central and local government investments. Note that the thick and thin black contour lines represent the 5% and 10% significance levels, respectively. Furthermore, Figure 4 shows the phase differences between these series at business cycle frequencies and at lower frequencies.

From these figures, the main findings are summarized as follows. Until about the mid-1990s, there is a large region of significant coherency at business cycle frequencies and the phase differences move in the vicinity of zero. This suggests that the public sectors act as a unit to smooth business fluctuations before facing an era of low growth. On the other hand, there is no significant coherency at business cycle frequencies and the phase differences are different from zero from the mid-1990s to the late 2000s. After the Great Recession in 2008, the coherency is again statistically significant and the phase differences take approximately zero at business cycle frequencies. These are consistent with the above band-pass filter results, while providing more detailed information.

A final analysis concerns the relationship between public investment and business cycles. Taking into account an essential point that fine-tuning is a necessary condition for fiscal policies to be effective, one primary interest here is the extent to which public investments move counter-cyclically. Figure 5 displays the wavelet coherency between public investment and industrial production. Disregarding the resemblance between the regions in Panels A and B of Figure 5, we detect that, while there is significant coherency at business cycle frequencies from the mid-1990s to the Great Recession in Panel A of the figure, we can hardly observe it in Panel B. In other words, local government investments have no connection with output in the period.

The most important point to note here is that the difference during the lost two decades appears at the range of 2.5–4 years, which is narrower than our benchmark business cycles (i.e., 2.5–7 years). This offers an illustration that, even within a typical business cycle frequency range, the nexus between economic variables is non-uniform and changes quickly over time. We then split the benchmark range between 2.5–4 and 4–7 years, and we present their phase differences in Figure 6. These charts show the different relationships that occur at the same time but at distinct frequencies (2.5–4 and 4–7 years), especially in the case of central government. Corresponding to the significant regions for the above wavelet coherency, the phase difference between central government investment and output is out of phase and

exhibits the countercyclical behavior of central government. It also reveals that local public investments are approximately in phase in the 1990s and 2000s except when in the vicinity of the Great Recession, implying that they are not countercyclical in that period.<sup>5</sup>

Turning to the results for the wavelet coherency and phase difference between public investment and effective job offer rate in Figures 7 and 8, these mostly reinforce the above findings. Compared to the output case, the coherency exhibits a clearer difference between central and local government investments. The phase difference for central government's behavior depicted in Panel A of Figure 8 is apparently inconsistent with the output case, but we can abstract the same implication from the chart in the sense that the phase difference is out of phase and central government investment moves in a countercyclical direction to effective job offer rate, corresponding to the significant regions for the wavelet coherency shown in Panel A of Figure 7. Likewise, broadly similar outcomes emerge in the case of local government investment as well.

All the results during the lost two decades are consistent with Miyazaki (2008, 2009) and provide a reason why local government investments have not yielded fiscal stimulus effects. To explain the ineffectiveness of local government investments, Miyazaki (2008) raises three possibilities: (1) useless content, (2) reduction in private demand caused by rising interest rates, and (3) the effect of substituting private consumption. While our results and these possibilities are not mutually exclusive, our view is different from these suggestions and more involved with the timing. That is, we conclude that local government investments are not implemented with adequate timing to stabilize economic fluctuations, and they fall far short of fine-tuning.

It follows from the above evidence that a countercyclical pattern of the aggregate public investments diminishes from the beginning of the 1990s to the Great Recession owing to the behavior of local governments.<sup>6</sup> As an inevitable consequence, the effects of fiscal policies in Japan weakened after the 1990s (as in Bayoumi, 2001; Ihori et al., 2003; Brückner and Tuladhar, 2010).

### 3.3 Interpretation

What were the sources of these breaks in the relationship between public investment by the central government and that by local governments? Why did local governments get out of step with central government in the mid-1990s? Why were local

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<sup>5</sup>When observing the phase difference of 2.5–7 years, we found no evidence that central government investments are clearly countercyclical.

<sup>6</sup>See Appendix B for the results of the aggregate public investments.

governments in tandem again with central government in the Great Recession?

A possible explanation for such breaks in Japanese fiscal policy is related to the fact that Japanese local public finance deteriorated after the burst of the bubble economy in the beginning of the 1990s. Noting that public investment by local governments is divided into subsidized and non-subsidized projects, Miyazaki (2008) argues that local governments had no other choice but to reduce the non-subsidized projects due to the deterioration of local public finance. Regarding local government investments, Funashima et al. (2014) further indicates that, whereas the subsidized expense is countercyclical to the business cycles, non-subsidized expense shows no reaction to macroeconomic movements because of the fiscal rigidity of local governments, particularly in the 2000s.

Our findings are consistent with such suggestions by Miyazaki (2008) and Funashima et al. (2014). Similar to their analyses, in Figure 9 we plot the implementation rate of local government investment. For comparison, we also plot the implementation rate of subsidized and non-subsidized expenses. The implementation rate is obtained by dividing settled accounts by the fiscal plans of local governments and multiplying by 100. From the figure, the implementation rate of non-subsidized expenses decreases in the period from the mid-1990s to the Great Recession. In summary, the coordination failure is attributed to the non-subsidized expenses that tend to reflect local government's discretionary behavior. Specifically, local governments reduce the non-subsidized expenses due to the deterioration of local public finance, even if central government urges them to increase public investments.

Finally, there is a need to consider the reason why local governments coordinate again with central government in the Great Recession. While it seems difficult to conclusively pinpoint the causes of such a structural shift, some candidates can be considered. First, since the global financial crisis in 2008 entailed a very large peak-to-trough fall, local governments had to cope with the abrupt economic slowdown. Second, the government's fiscal condition is relevant. As is well known, fiscal reconstruction and structural reform were undertaken under the administration of Junichiro Koizumi from April 2001 to September 2006. As a result of the fiscal structural reform, as stated in Doi and Ihuri (2009), the primary balance of the central and local governments as a percentage of GDP has been decreasing since fiscal year 2003, so that a 1 percent surplus in the local primary balance was achieved in fiscal year 2007. Hence, local governments were able to execute the non-subsidized projects according to the fiscal plans in the Great Recession. In addition to the improvement of the local public finance, another possible reason may be that the fiscal stimulus package is relatively small-scale in nature.

## 4 Conclusion

While many studies have now documented the effects of public investment in Japan, almost all of them nonetheless fail to distinguish between public investment by the central government and that by local governments. In this paper, we attempt to explore the changing dynamics of macroeconomic policy coordination between Japanese central and local governments by using modern wavelet techniques. The results of this paper reveal the governments' one-time failure of coordination in nearly a half-century and identify the period with some plausible interpretations.

In macroeconomic stabilization terms, we can briefly restate that local government investments failed to coordinate with central government investments during the lost two decades, although public investments have played some role in offsetting business cycles before the burst of the bubble economy in the beginning of the 1990s and after the recent Great Recession. This coordination failure is contributory to the ineffectiveness of fiscal stimulus and supports the results of our predecessors, who indicate that discretionary fiscal policies became less effective in the 1990s (i.e., the lost decade) in Japan. In light of the fact that the majority of public investment is implemented by local governments, our wavelet results demonstrate that fiscal policies have not been implemented with adequate timing to stabilize economic fluctuations throughout most of the lost two decades.

As stated in Oates (1972), it seems a normative consensus that stabilization policy ought to be implemented not by local governments but by central government. In the Japanese case, the fiscal relationship between the central and local governments is centralized, and the stabilization policy is planned by the central government. However, in reality, to the extent that Japan is concerned, most public investments are implemented by local governments, who sometimes tend to have an incentive to deviate from the central government's plan.

## Appendix A

Table 1 shows the correlation coefficients between business cycle components. We used three selective subsample periods: 1969:5–1993:10, 1993:10–2008:2, and 2008:2–2013:3, and thereby compared the calculated correlation coefficients for the three subsamples. The subsamples were divided on the basis of noticeable breaks in the relationship between the business cycle components, and the first dividing point (October 1993) corresponds to the trough of the first recession in the 1990s, and the second dividing point (February 2008) corresponds to the peak of economic expansion in the vicinity of the Great Recession in 2008.

From the table, we can formally ascertain the outcomes provided by Figure 1 as follows. The correlation coefficients between central and local government investments uncover the extremely weak association in the middle subsample (1993:10–2008:2). Stemming from this, while central government investment is negatively correlated with output in all cases, there is no correlation between local government investment and output in the middle period. As for effective job offer rate, it should be noted that it exhibits different behavior from output in the last subsample (2008:2–2013:3), as shown in Figure 10. To the extent that the band-pass filter result is concerned, the movement of effective job offer rate deviates from the “date of business cycles” by the Cabinet Office for the Government of Japan. Consequently, we can state that, even when output is replaced by effective job offer rate, very similar implications emerge.

## Appendix B

Here, we present the wavelet results of the aggregate public investment, which includes both central and local government investments. The aggregate series was seasonally adjusted, and we use the monthly growth rate as before. Figures 11 and 12 display these results for industrial production and effective job offer rate, respectively. In both of these cases, during the lost two decades, the coherency is high and significant at business cycle frequencies only in the vicinity of the Great Recession in 2008, and the phase differences are out of phase. In other words, when it comes to the aggregate public investment after the burst of the bubble economy in the early 1990s, we can observe a strongly countercyclical pattern only in the recent Great Recession.

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Table 1: Correlation coefficients of business cycle components by a band-pass filter

	$G^L$	$Y$	$E$
A. 1969:5-1993:10			
$G^C$	0.6332	-0.5812	-0.6136
$G^L$	1.0000	-0.3883	-0.3848
B. 1993:10-2008:2			
$G^C$	0.1042	-0.5716	-0.5195
$G^L$	1.0000	0.0472	0.4656
C. 2008:2-2013:3			
$G^C$	0.9793	-0.7230	-0.1773
$G^L$	1.0000	-0.7554	-0.3062

*Notes:*  $G^C$  is central government investment,  $G^L$  is local government investment,  $Y$  is industrial production, and  $E$  is effective job offer rate.



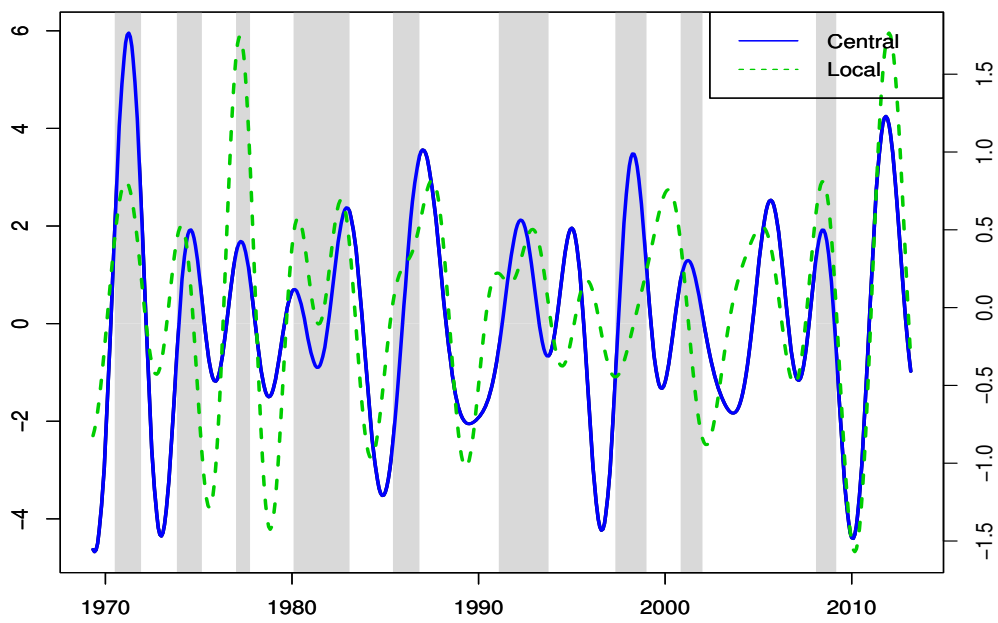
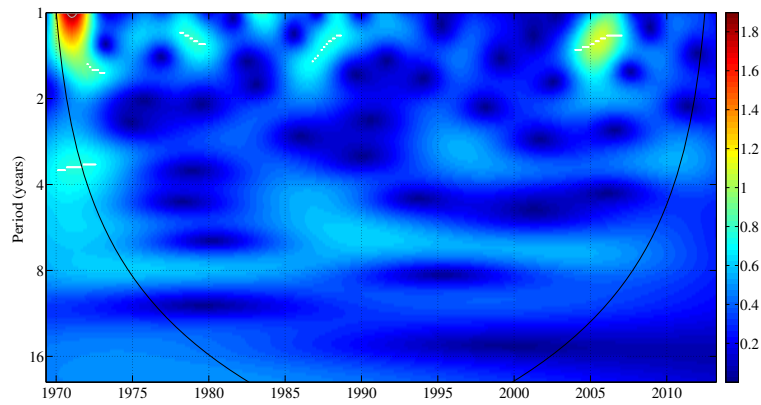


Figure 1: Business cycle components

*Note:* Shaded areas indicate the Cabinet Office for the Government of Japan's recessions.

### A. Central government investments



### B. Local government investments

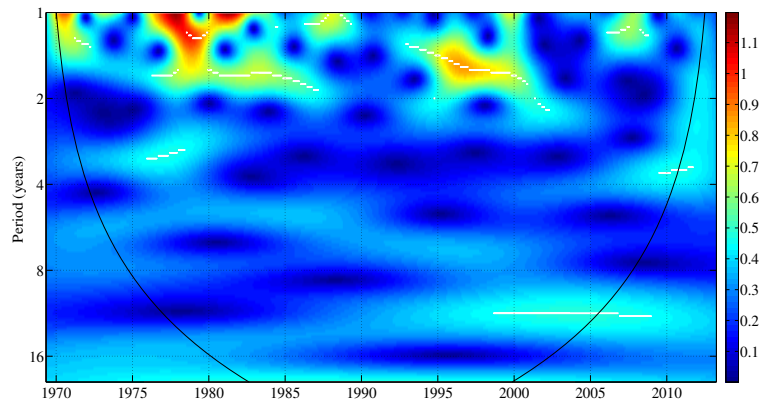


Figure 2: Wavelet power spectrum

*Notes:* The thick and thin black contours respectively stand for the 5% and 10% significance levels. The white lines represent the maxima of the wavelet power spectrum and the black line represents the cone of influence.

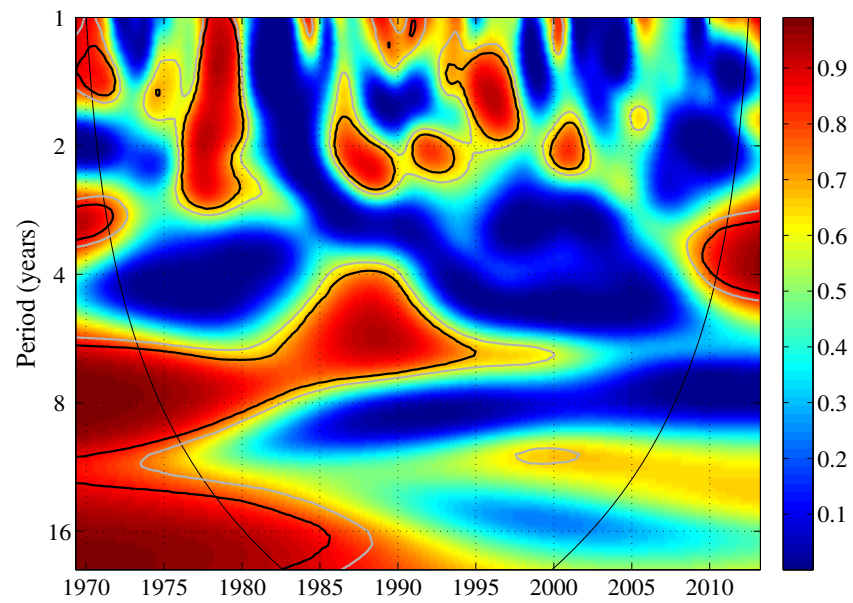


Figure 3: Coherency between central and local government investments

*Notes:* The thick and thin black contours respectively stand for the 5% and 10% significance levels. The black line represents the cone of influence.

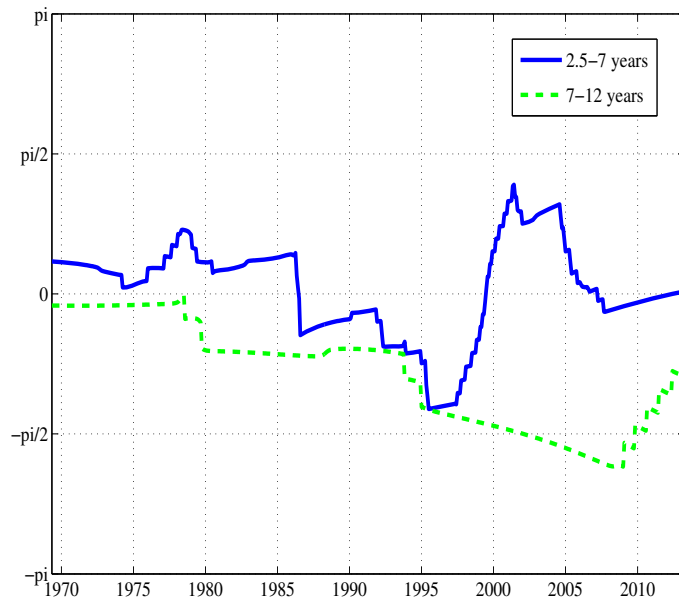
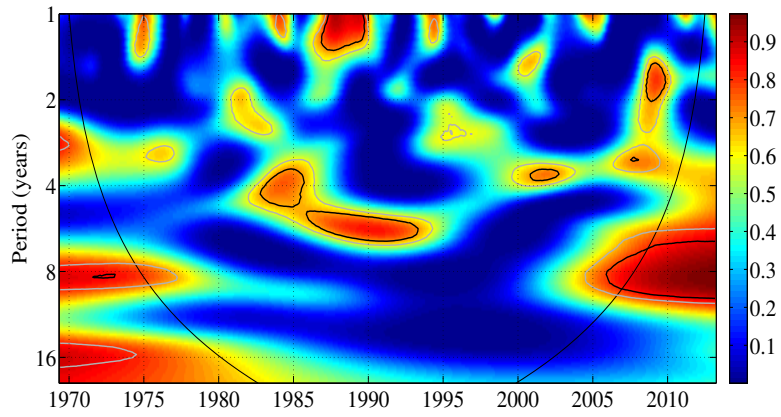


Figure 4: Phase difference between local and central government investments

### A. Central government investments



### B. Local government investments

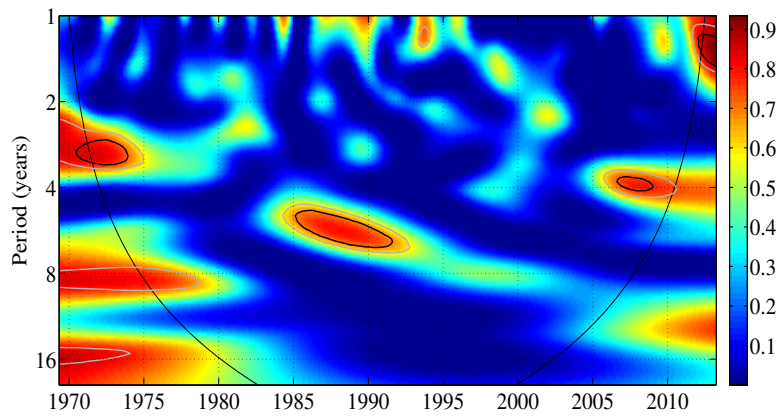
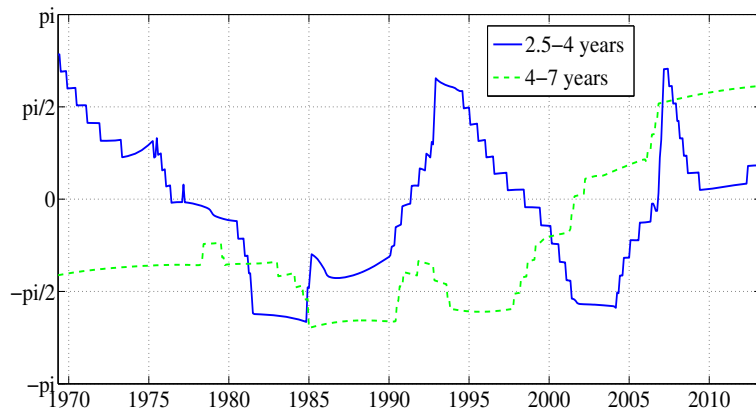


Figure 5: Coherency between public investment and industrial production

*Notes:* The thick and thin black contours respectively stand for the 5% and 10% significance levels. The black line represents the cone of influence.

### A. Central government investments



### B. Local government investments

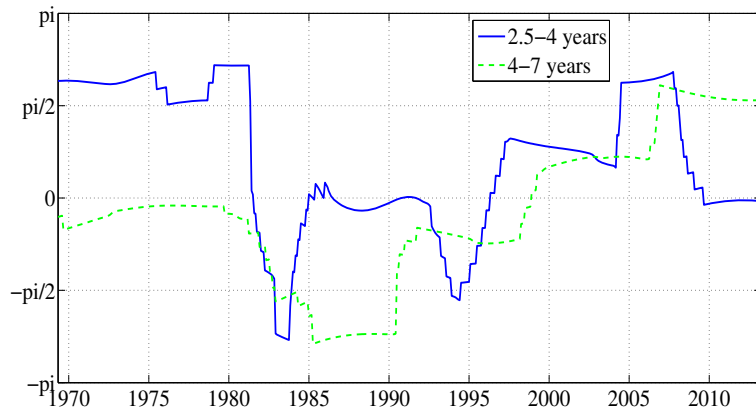
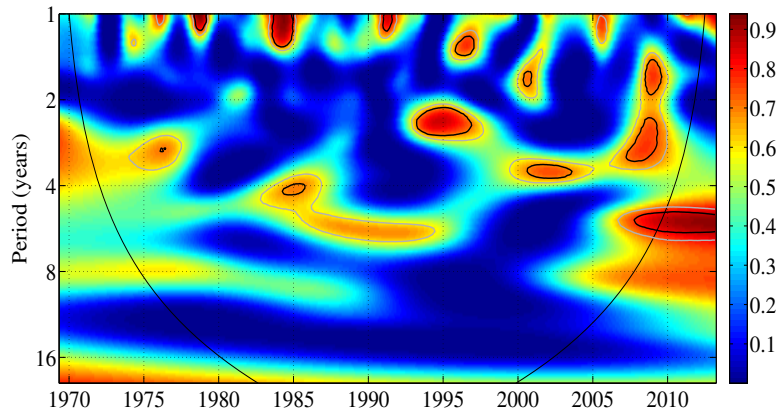


Figure 6: Phase difference between public investment and industrial production

A. Central government investments



B. Local government investments

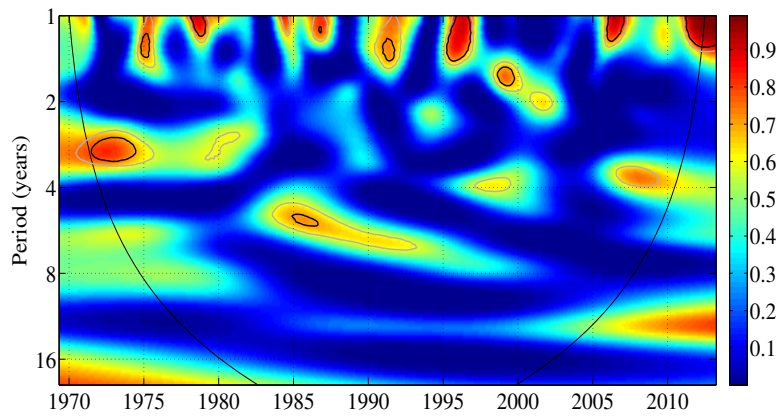
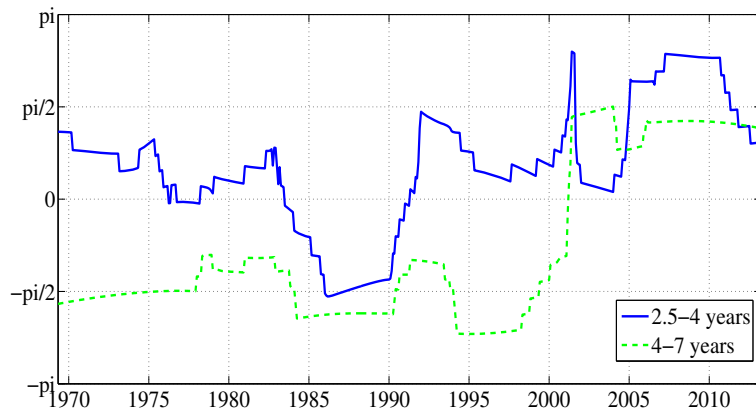


Figure 7: Coherency between public investment and job rate

*Notes:* The thick and thin black contours respectively stand for the 5% and 10% significance levels. The black line represents the cone of influence.

### A. Central government investments



### B. Local government investments

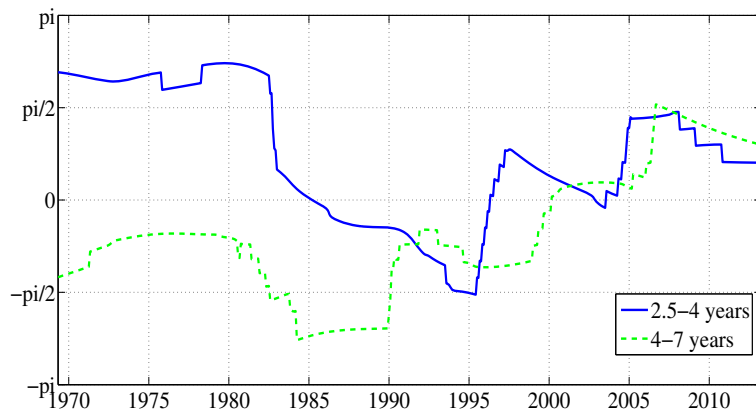


Figure 8: Phase difference between public investment and job rate



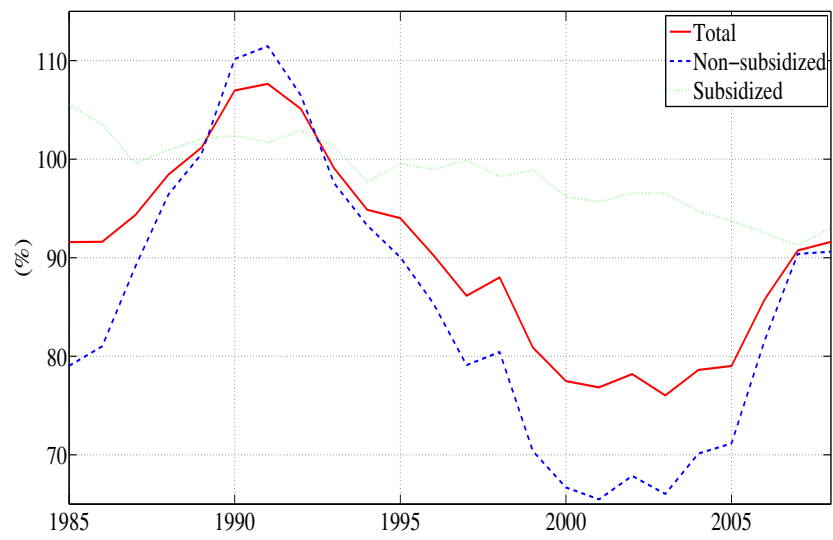


Figure 9: Implementation rate of local government investments

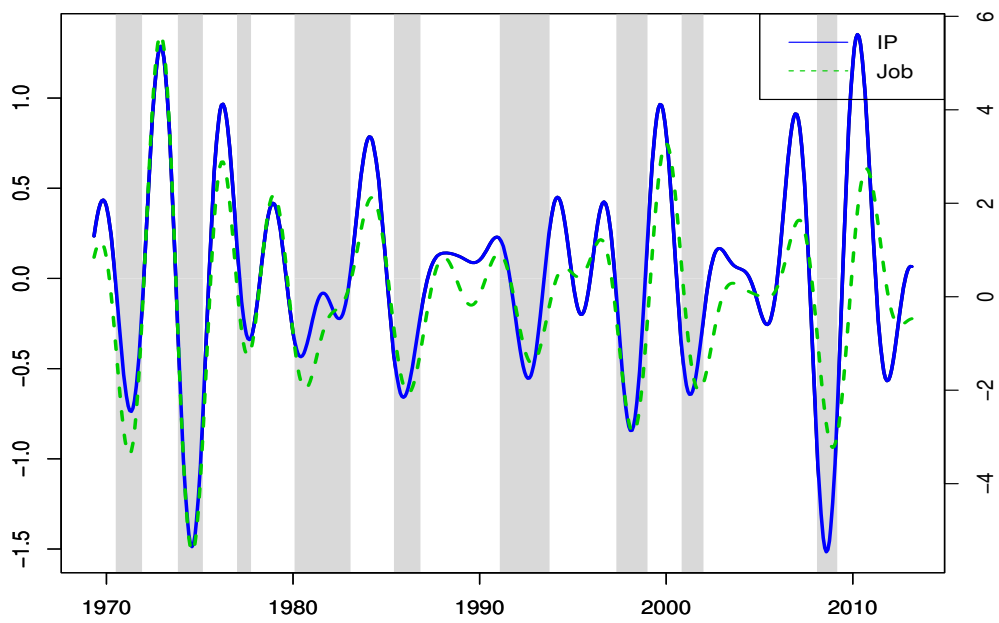
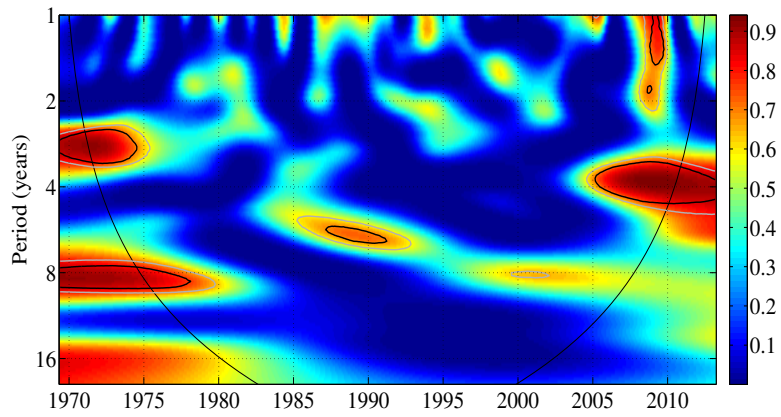


Figure 10: Business cycle components of business conditions

*Note:* Shaded areas indicate the Cabinet Office for the Government of Japan's recessions.

### A. Coherency



### B. Phase difference

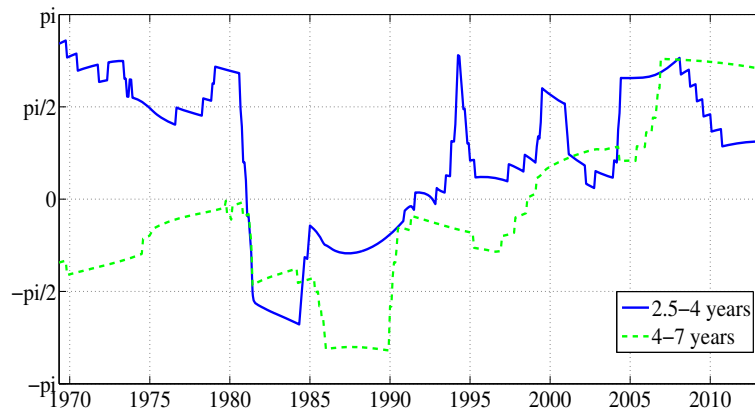
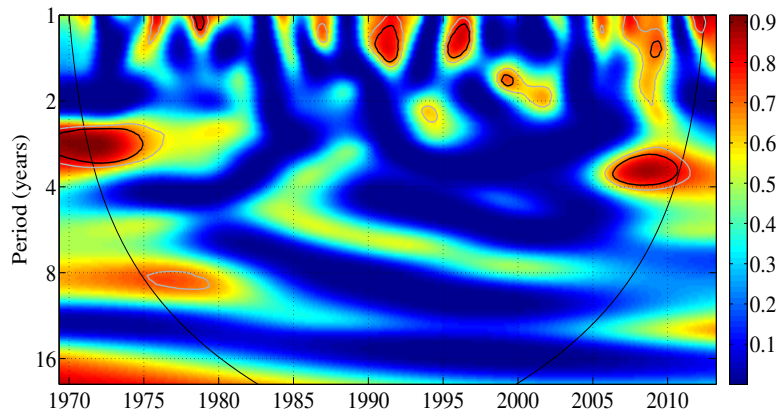


Figure 11: Aggregate public investment and industrial production

*Notes:* In Panel A the thick and thin black contours respectively stand for the 5% and 10% significance levels. The black line represents the cone of influence.

### A. Coherency



### B. Phase difference

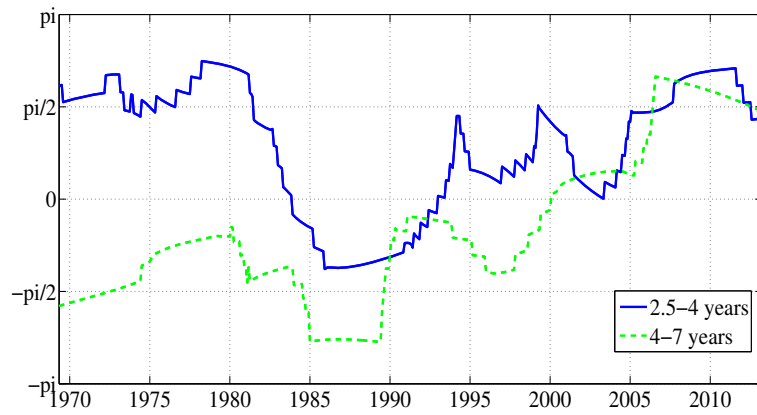


Figure 12: Aggregate public investment and job rate

*Notes:* In Panel A the thick and thin black contours respectively stand for the 5% and 10% significance levels. The black line represents the cone of influence.