The Effects of Macroeconomic Shocks on Inter-Provincial GDP Disparities in China: Estimates from a Restricted VAR Model

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Abstract

The extent of inter-regional disparities is an important policy issue in China and the sources of these disparities have been subject to considerable empirical research. Yet we have relatively little empirical knowledge of the effects on disparities of shocks to national macroeconomic variables such as GDP, investment and government expenditure. This is an important gap in the empirical literature since much government policy seeks to influence variables such as GDP or uses variables such as government expenditure as a macroeconomic instrument. To the extent that these shocks have predictable consequences for disparities, policy-makers need to know the sign, size and timing of such effects before making policy decisions. We simulate the effects of aggregate shocks on individual provinces' GDP within the framework of a vector autoregressive (VAR) model restricted in a manner following Lastrapes (*Economics Letters* 2005). We use annual data from 1953 to 2010 to estimate the model which includes all of China's provinces and simulate the effects of a variety of aggregate shocks on provincial outputs. We find great diversity of effects across the provinces and also variability across the effects of different aggregate shocks but little evidence of a systematic influence of aggregate shocks on the distribution of their effects across the provinces.

Keywords: regional disparities, economic growth, China

JEL categories: E61, R50, O53

1. Introduction

Although China has steadily climbed up the country league-table in terms of GDP per capita since opening-up and reforms began to take hold in the 1980s, there have been substantial and persistent problems with the distribution of this growing output.[1] In this paper we focus on the regional distribution of GDP, taking the provinces as the regions. The distribution of GDP per capita has fluctuated over the period since the beginning of reforms, with the coefficient of variation falling steadily over two decades from the late 1970s until the late 1990s, when it began to rise so that by 2004 it returned to the level of the mid-1980s, after which it declined steadily to the end of the decade.[2] Despite recent declines in inter-regional inequality, the ratio of GDP per capita in the poorest province in 2010 (Guizhou) to that of the richest (Zhejiang) was still 3.8, a very large disparity by any standards.[3]

Inter-regional disparities have been a perennial policy issue at the highest levels of Chinese policy-making since the inception of the People's Republic of China, with disproportionately large allocations of investment to the interior region occurring during much of Mao Zedong's rule. Subsequent to the beginning of reforms under Deng Xiaoping, allocation of resources swung towards the coast on the basis of the argument that investment was likely to be most productive there and that, eventually, the growing coast would drag the rest of the country with it to general prosperity. By and large, this has not happened and during the 1990s policy-makers increasingly re-focussed on the problems of large and persistent differences in per capita GDP across the provinces.[4]

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[1] China's ranking on the basis of GNI per capita in World Bank tables rose from 140th in 1990 to 129th in 2000 and 74th in 2012. See http://data.worldbank.org/indicator/NY.GNP.PCAP.CD, accessed 24 October, 2013.

[2] This characterisation is based on the coefficient of variation for nominal provincial GDP from 1953 to 2010. The source of the data is described in the data section below.

[3] The question of exactly whether, and, if so, how and when regional economies in China have been converging has been the subject of a great deal of empirical research. To survey this would take us too far afield in this introduction but see Groenewold *et al.* (2008) Chapter 2 and the interesting recent contribution by Andersson *et al.* (2013) and references there.

[4] See Groenewold *et al.* (2008), Chapter 3 for more information on Chinese regional policy since the founding of the People's Republic of China.

Policies to reduce regional disparities are clearly desirable on the basis of equity and have also been supported on the basis of the danger of social unrest which might be caused by widening gaps between rich and poor regions. Yet, there has been a noticeable caution in the vigour with which such policies are pursued by policy makers who are reluctant to jeopardise the continuation of a high aggregate growth rate. This has been particularly true in light of the recent growth slowdown following the Global Financial Crisis. Thus, there is, in some quarters at least, a perception that directing policy to reduce regional inequality may have a cost in terms of lower national performance, a perception not restricted to policy-makers but also evident in the research literature. Thus, e.g., Wong (2006) asserts that inequality is an inevitable consequence of growth policy in China and only its severity is surprising. Similarly, Knight (2008), argues that income inequality is unavoidable, at least in the early stages of development. Further, Zhu and Wan (2012) find a trade-off between growth and equality and argue that if China is to foster a balanced and harmonious economy, there must be a shift in focus from growth to equality.

Of course, those familiar with the literature on economic development and on regional development in particular, will realise that the consideration of such a trade-off is not new. Indeed, it dates back at least to the work on the inverted-U curve between economic development and regional inequality; see particularly Williamson (1965) and earlier work by Kuznets (1955) and Myrdal (1957) and Hirschman (1958). The idea captured by the inverted-U curve is that in the early stages of development regional (and other) inequality rises but eventually falls as development (usually measured in terms of income or output per capita) proceeds. There is thus a relationship between inequality and development which has an inverted-U shape.

A substantial theoretical and empirical literature has developed in the area of growth and inequality but little consensus has been reached. Thus theoretical analysis in papers by

Galor and Zeira (1993), Alesina and Rodrik (1994), Persson and Tabellini (1994) and Benhabib and Rustichini (1996) present arguments that growth and inequality are negatively related while Kaldor (1956), Benabou (1996), Edin and Topel (1997) argue the opposite. Empirical work is equally inconclusive with the work reported in papers by Alesina and Rodrik (1994) and Persson and Tabellini (1994) finding that inequality is harmful for growth while Forbes (2000) reports the opposite finding and various papers present ambiguous results including those by Barro (2000), Partridge (2005), Fallah and Partridge(2007), Chambers (2007), Bjornskov (2008) and Barro (2008).

The literature on inequality and development in China is relatively sparse. Kuijs and Wang (2005) argue that China can have a more balanced growth path with a sustainable reduction of income inequality if appropriate policies, such as reducing subsidies to industry and investment, encouraging the development of the services industry and reducing the barriers to labour mobility are implemented. Wan *et al.* (2006) explicitly tested the growth-inequality nexus in China, focusing on rural-urban income inequality and regional growth using a provincial-level panel data set. They found that an increase in inequality has negative effects on growth, irrespective of time horizons. Qiao *et al.* (2008) find that fiscal decentralisation has resulted in more rapid economic growth accompanied by greater regional inequality. In a more recent test of the possible growth cost of reducing regional inequality, Chen (2010) tested the relationship between growth in per capita GDP and the Gini coefficient as a measure of inter-regional inequality in a multivariate time-series model and found that a reduction in inequality comes at the cost of growth in the short run but not in the long run. On the basis of a mixture of theoretical and empirical analysis, Zheng and Kuroda (2013) argue that whether there is a trade-off between growth and regional equality depends on the driver of growth – if growth is driven by transportation infrastructure expenditure, it comes at the cost of increased inequality while the opposite is true if growth is generated by investment in knowledge infrastructure.

To sum up, there is a substantial literature, both theoretical and empirical, in the broadly-defined area of inequality and development but no consensus on the direction of the relationship between them. Moreover, there is relatively little work which deals explicitly with China.

In the work reported in this paper we use a novel empirical approach to the question of whether an increase in growth reduces or exacerbates existing regional disparities and we go on to evaluate the direct effects of policies which might be used to boost growth such as increases in investment and government expenditure.

The method we propose to use is based on a restricted VAR model recently developed and used by Lastrapes (2005) to analyse the relationship between changes in the aggregate inflation rate and the dispersion of individual prices. Applying this to the regional growth context allows us to trace through the effects of a change in an aggregate variable such as the growth rate on the per capita GDP of all provinces rather than on a single summary measure of the distribution such as the coefficient of variation or the Gini coefficient, as has invariably been the case in existing work.

We find great diversity of effects across the provinces and also variability across the effects of different aggregate shocks but little evidence of a systematic influence of aggregate shocks on the distribution of their effects across the provinces.

The remainder of the paper is structured as follows. In section 2 we set out the empirical model based on the work of Lastrapes. The data to be used are described in section 3. The results for the base model are reported in sections 4 with extensions discussed in section 5. Conclusions are drawn in the final section.

2. The empirical model

As observed in the previous section, existing empirical literature which examines the effect of growth shocks on regional disparities uses a summary measure of disparities such as the Gini coefficient or the coefficient of variation calculated on the cross-section of regional GDP per capita values. This makes the analysis tractable but loses much of the information about the distribution across regions as well as information on the response of individual regions to aggregate shocks. An alternative approach is to estimate and simulate a model which includes the aggregate variables such as the national growth rate as well as all the regional per capita GDP variables. This is possible if there are relatively few regions so that there are sufficient degrees of freedom given the size of the data sample. Where this is not the case the estimation of such a model becomes intractable unless restrictions are imposed to reduce the number of parameters which must be estimated. Lastrapes (2005) proposes such a set of restrictions and in Lastrapes (2006) applies the method to the analysis of the effects of aggregate inflation shocks on the distribution of individual prices. Subsequent applications of the method include Beckworth (2010) and Fraser *et al* (2012), both of whom applied it to problems where the disaggregated variables had a regional dimension; indeed, both analysed the issue of whether aggregate monetary shocks had uniform effects across regions – the states of the US in Beckworth's case and the states of Australia in the application by Fraser *et al.*

We wish to analyse the effects of aggregate macroeconomic shocks on individual provincial GDP variables in China. With 31 provinces and annual GDP data for (at most) 60 years, estimation of a VAR would run into degrees-of-freedom problems very quickly so that the Lastrapes procedure seems ideally suited to this application.

The Lastrapes approach can be developed as follows. Consider a vector of variables, $\boldsymbol{z}_t$ which includes both national and regional variables. Partition $\boldsymbol{z}_t$ into two parts,

(1) $z_t = (z_{1t}, z_{2t})'$

where the first component consists of the regional variables (regional per capita GDPs) and the second consists of the national variables. It is expected that there are many regional variables and few national variables. Assume that the elements of $\boldsymbol{z_t}$ are related by a structural dynamic model of the form:

(2) $\boldsymbol{A_0 z_t = A_1 z_{t-1} + \ldots + A_p z_{t-p} + u_t = A(L) z_t + u_t}$

Where $\boldsymbol{A(L)}$ is a polynomial in the lag operator, L, $\boldsymbol{A(L) = A_1 L + \ldots + A_p L^p}$ and the error process satisfies $E(\boldsymbol{u_t}) = \boldsymbol{0}$ and $\mathrm{E}(\boldsymbol{u_t u_t'}) = \boldsymbol{I}$, the identity matrix. Thus the errors in the structural model (the structural errors) are assumed independent and the equations of the model are normalised to ensure a unit variance for each error.

There are two difficulties in using the model as it stands. The first is that it is not identified – all the equations in (2) have the same variables. This is a standard problem with structural models of this type and requires additional restrictions to be placed on the model, the most common of which are short-run Bernanke-Sims restrictions (including those based on the Cholesky decomposition of the variance matrix of the errors) and the long-run Blanchard-Quah restrictions.[5] In either case the model is first transformed into a reduced-form one by pre-multiplying by the inverse of the matrix $\boldsymbol{A_0}$ to obtain:

(3) $z_t = \boldsymbol{A_0^{-1} A}(\mathrm{L}) z_t + \boldsymbol{A_0^{-1} u_t} \equiv \boldsymbol{B}(\mathrm{L}) z_t + \boldsymbol{\varepsilon_t}$

where $\boldsymbol{B}(\mathrm{L}) \equiv \boldsymbol{A_0^{-1} A}(\mathrm{L})$ and $\boldsymbol{\varepsilon_t} \equiv \boldsymbol{A_0^{-1} u_t}$. The reduced-form model can be estimated by OLS and the restrictions used to identify the elements of the $\boldsymbol{A_0}$ matrix which can then be used to retrieve the structural parameters and errors from their reduced-form counterparts. The retrieval of the structural errors is important since the reduced-form errors will be correlated with each other (each is a linear combination of all the same structural errors), making it

[5] See Enders (2010) for a textbook treatment of these issues.

illegitimate to shock them independently. The structural errors are, by assumption, uncorrelated and therefore can be shocked independently.

The second difficulty likely to be faced in the estimation of model (2) is a degrees-of-freedom problem that arises if there are many regional variables relative to the number of observations in the sample period. Lastrapes (2005) developed a method for overcoming this problem in a model in which there were a small number of aggregate variables (national variables in our case) and a large number of disaggregated variables (regional variables in our application). He proposed two assumptions: (i) the aggregate variables are block exogenous, and (ii) the disaggregated variables are independent of each other once they have been conditioned on the aggregate variables. The first of these assumptions implies that an individual disaggregated variable does not (Granger-) cause any of the aggregate variables and the second implies that the disaggregated variables are mutually correlated only insofar as they are related to common aggregate variables. Under these assumptions, Lastrapes showed that the model could be written as two components, one a standard VAR in the aggregate variables and the other a series of individual equations for the disaggregated variables. In particular:

(4a) $$\boldsymbol{z_{1t}} = \sum_{i=1}^{p} \boldsymbol{B}_{11}^{i} \boldsymbol{z_{1t\text{-}i}} + \sum_{i=0}^{p} \boldsymbol{G_i} \boldsymbol{z_{2t\text{-}i}} + \boldsymbol{v_t}$$

(4b) $$\boldsymbol{z_{2t}} = \sum_{i=1}^{p} \boldsymbol{B}_{22}^{i} \boldsymbol{z_{2t\text{-}i}} + \boldsymbol{e_{2t}}$$

The equations in (4b) are simply a standard VAR in the aggregate variables and can legitimately be estimated by OLS. Since we are interested in shocking the errors in the equations only for the aggregate variables, identification of the structural errors is necessary only for the VAR in (4b) and can be based on commonly used restrictions for VARs mentioned earlier. Lastrapes shows that the matrix $\boldsymbol{B_{11}^{i}}$ in equations (4a) is diagonal so that each of the equations for the disaggregated variables has only lags of the dependent variable and current and lagged values of the aggregate variables as regressors. The assumption of the block exogeneity of the aggregate variables ensures that there is no contemporaneous correlation between the regressors and the errors terms in the equations. In addition Lastrapes shows that the covariance matrix of the errors in (4a) is diagonal so that there is no gain to be had from estimating the equations simultaneously by the Seemingly Unrelated Regressors Estimator. Hence, the equations in (4a) can legitimately be estimated one-by-one using OLS.

In our application, the aggregate variables will be national variables such as GDP, investment and government expenditure and the disaggregated variables will be provincial GDPs. In this paper we will use the Cholesky scheme for identifying the structural errors in the VAR part of the model. Alternatives such as the Bernanke-Sims and Blanchard-Quah methods mentioned above are also possible but we will leave those for future research.

3. The data

We require data for two types of variables: national and regional. All data are annual from 1953 to 2010.

The regional variables are real provincial GDP which in the base model we use in per capita terms. The data are taken from Wu (2004) and various issues of the *China Statistical Yearbook* and are in terms of yuan per capita in 1953 prices. We use data for 28 of China's 31 provinces (including the "city-provinces" of Beijing, Shanghai and Tianjin) with Chongqing included in Sichuan, Hainan included in Guangdong and Tibet excluded, all for reasons of missing data.

Three national variables were used: real GDP, real investment in fixed assets expenditure and real government expenditure. All are in 1953 prices, billions of yuan and taken from *New China 60 Years Statistics Compilation* (National Statistical Bureau, 2009) and *China Statistical Yearbook* (National Statistical Bureau, various issues). Population data also come from the *Statistical Yearbook* and were used to convert all three aggregate variables to per capita form (all in yuan per capita, 1953 prices).

Before proceeding with the estimation and simulation of the mode, we test the data for stationarity using an augmented Dickey-Fuller test. The results for the (logs of) provincial real GDP per capita are in Table 1 and for the three aggregate variables (also in log real per capita form) in Table 2.

[Tables 1 and 2 about here]

While there are some exceptions, most of the series appear to be I(1) and we proceed as Lastrapes (2006) and Beckworth (2010) did and work with variables in first differences to ensure that the VAR is stationary.

4. Results: base case

We begin with the simplest case of a single aggregate variable, real GDP, and work with all variables in log real per capita form. With only a single aggregate variable, the VAR part of the model (corresponding to equation (4b)) is a single equation and the issue of identification of the structural errors does not arise since there is only a single aggregate error which is both structural and reduced-form. The block-exogeneity assumption ensures that the VAR error is independent of the errors of the regional equations and so can be estimate by OLS. The model is estimated in first difference form and the impulse response functions (IRFs) are accumulated so that they may be interpreted as levels. The IRF for aggregate GDP following a unit GDP shock, together with confidence bounds, is illustrated in Figure 1. The effect on GDP of the shock is permanent and positive, rising from a value of 1 to a level of approximately 1.75. Most of the rise has been completed after 5 years. The effect is clearly significant by conventional standards.

[Figure 1 about here]

The next step is to generate similar IRFs for the provincial GDP variables. We do this by feeding the effects of the shock on national GDP into the estimated provincial equations, taking account of the dynamics both at national and regional levels. The effects for the full sample (1953-2010) are reported in Figure 2.

[Figure 2 about here]

The IRFs show considerable diversity; there is clear evidence that a shock to national GDP is very unevenly distributed across the provinces. More than half of the regional IRFs lie outside the confidence bounds for the national IRF and are significantly different from it in this sense.[6] As expected, about half the regional IRFs are above the national IRF and about half below. Only two are approximately coincident with the national IRF.

There are no obvious patterns in the regional-national differences. If we group the provinces into traditional categories of coastal, central and western regions, we find that in the coast approximately half the provinces were significantly above and half significantly below the national level; in the central region somewhat more were above than below and in the west more were below than above. Hence there does not seem to be a bias in favour of one region or another so that there is no evidence that either the poorer provinces in the west were favoured by government policy or that the richer provinces in the coast were rich because they were better able to take advantage of national expansionary policy. That there was no "bias to the poor" is clear from the observation that not only poor provinces like such as Sichuan, Anhui and Shaanxi were significantly above the national level, but so were

[6] Note that, strictly speaking, a test of significance of the difference between the national and the regional IRF should take account of the distribution of both. We follow Fraser *et al.* (2012) and report just the confidence bounds for the national IRF and ask whether the regional IRF falls within these bounds.

wealthier provinces such as Zhejiang. On the other hand, not only rich provinces such as Beijing and Shanghai performed significantly below average but so did poor provinces such as Guangxi, Guizhou and Yunnan.

More formal evidence on the relationship between relative performance and the ranking of the provinces in the real per capita GDP tables was obtained by regressing the deviation of the provincial IRF from the national IRF after 10 period (the" long-run") on the provincial real per capita GDP level. If there was a bias to the poor, we would expect that poorer provinces would benefit more than average from a national shock. To test this we regressed the IRF deviation (IRFDIFF) on the provincial real per capita GDP in 1953 (PROVGDP53) with the following result:

$$\text{IRFDIFF} = \underset{(0.62)}{-0.0796} + \underset{(1.72)}{0.0010}\ \text{PROVGDP53}, \qquad R^2 = 0.1000$$

where the figures in parentheses are absolute t-ratios. The coefficient on PROVGDP53 is significant at the 10% level and positive, providing some evidence against the hypothesis since the richer provinces tended to benefit more from national shocks.

Another hypothesis, not necessarily inconsistent with the one just tested is that the provinces which finished up rich in 2010 did so because they were able better to benefit from national shocks than others were. We tested this by regressing the provincial GDP in 2010 on the IRF deviation with the result:

$$\text{PROVGDP10} = \underset{(0.00)}{6883.4768} + \underset{(1.64)}{3995.1738}\ \text{IRFDIFF}, \qquad R^2 = 0.09$$

There is weak evidence of a positive effect: provinces which were well-off at the end of the sample period were able to take better advantage of the effects of national expansion. Whether the rich provinces grew more than they otherwise would have can be tested by regressing the ratio of GDP in 2010 to that in 1953 (RATIO10/53) on the IRF deviation:

$$\text{RATIO10/53} = 44.1793 - 4.8022\ \text{IRFDIFF}, \qquad R^2 = 0.02$$
$$(13.54) \qquad (0.69)$$

The slope coefficient is insignificant so that there is no evidence to support this view.

Thus, all in all, there is considerable diversity in the way in which the provinces reacted to a change in national GDP, but little discernible pattern to the diversity. It is possible that this lack of a discernible pattern is at least partly due to the long sample period and the great changes which have occurred between 1953 and 2010. We therefore proceed, in the next section, to split the sample at 1980 to coincide with the beginning of reforms and the opening of the Chinese economy both to greater economic interaction with the rest of the world and a greater internal economic flexibility.

5. Results: extensions

In this section we extend the results reported for the base case in a variety of ways. First, we consider the base-case model estimated over two sub-samples: 1953-1979 and 1980-2010. Then we consider the effects on the results of extending the lags in the model from one to two. Next we introduce an extra aggregate variable into both the VAR part of the model and the individual provincial equations. This allows us to assess whether the effects of a GDP shock are sensitive to the presence of a second variable in the VAR model and also to analyse the effects of shocks to the second variable itself. We experiment with four additional variables, one at a time: investment, exports, trade and government expenditure. In each case we carried out the analysis with a model with two lags and distinguished three sample periods: 1953-2010, 1953-1979 and 1980-2010.

5.1 Sub-samples

In this sub-section we report the results for two sub-samples, splitting the sample at 1980. The IRFs for the first sub-sample, from 1953 to 1979, are reported in Figure 3.

[Figure 3 about here]

In broad terms the results are similar to those for the full sample – there is considerable diversity with about half the provinces having responses which are significantly different to the national average. And, as was the case for the full sample, some rich provinces have IRFs significantly above the national IRF – Beijing, Shanghai and Tianjin are examples – while other well-off provinces such as Zhejiang and Jiangsu have responses significantly below the nation as a whole. Similarly, for the poorer provinces: some show above-average response (Guizhou, Shaanxi and Shanxi) and others have IRFs significantly below the national level (Guangxi, Gansu and Anhui).

Regressions were also run for this sub-sample similar to those reported for the whole sample above. The results are:

$$\underset{}{IRFDIFF} = \underset{(1.42)}{-0.3453} + \underset{(2.25)}{0.0024}\ PROVGDP53, \qquad R^2 = 0.1631$$

$$PROVGDP80 = \underset{(0.00)}{503.9616} + \underset{(2.30)}{295.2929}\ IRFDIFF, \qquad R^2 = 0.1991$$

$$RATIO80/53 = \underset{(20.99)}{2.7075} + \underset{(1.95)}{0.2793}\ IRFDIFF, \qquad R^2 = 0.1277$$

Clearly the results are more robust for this initial sub-sample. The first equation shows that provinces which started off the period with a relatively high per capita GDP on average experienced greater effects from national shocks – the reverse of a bias to the poor. The second and third equations show that greater-than-average responses to aggregate shocks tended to results in higher end-of-sample GDP levels.

The IRFs for the second sub-sample, 1980-2010, are shown in Figure 4.

[Figure 4 about here]

Again, the overall conclusions are similar to those drawn from the previous two sets of results – there is considerable diversity across the provinces in their reaction to an aggregate shock, although slightly less so than in the earlier sub-sample: in this case 11 of the 28 provinces have a significantly different IRF compared to the national IRF. This might reflect a greater national convergence in the second period after reforms enhanced regional integration. There are some dramatic changes from the first to the second sub-sample; some provinces such as Beijing, Shanghai and Guizhou switched from significantly above to significantly below the national response while others, such as Jiangsu, moved in the opposite direction. More details are shown in Table 3 which gives the rankings of the provinces according to their real per capita GDP in 1953, 1980, 2010 and the sample mean as well as a summary measure for each province of whether their IRF is above or below the national IRF.

[Table 3 about here]

A summary of the transitions from 1953-1979 to 1980-2010 is reported in Table 4

[Table 4 about here]

It is clear that the cells on the principal diagonal in Table 4 do not dominate as they would if there were a strong persistence of the classification from the first to the second sub-sample. In fact, there are just as many cases in the opposite diagonal suggesting that provinces were as likely to switch from above to below or *vice versa* as they were to stay above or below from the first sub-sample to the second. This distinct difference in the results over time is also evident in the cross-section regression results:

$$\text{IRFDIFF} = \underset{(0.53)}{0.1410} - \underset{(1.14)}{0.0003}\ \text{PROVGDP80}, \qquad R^2 = 0.0474$$

$$\text{PROVGDP10} = \underset{(6.16)}{7217.7595} - \underset{(0.28)}{364.7059}\ \text{IRFDIFF}, \qquad R^2 = 0.0031$$

$$\text{RATIO10/80} = \underset{(20.99)}{16.5474} + \underset{(2.81)}{3.0720}\ \text{IRFDIFF}, \qquad R^2 = 0.2332$$

In the first two equations the intercepts have changed sign from the previous sub-period (although they are now both insignificant): in 1980-2010 starting per capita GDP had a negative effect on the relative performance of the province and, on the other hand, the better the performance of the province relative to the nation as a whole, the lower the end-of-period per capita GDP. This latter result may, however, reflect the initial position since if we regress the ratio of the end-of-period GDP to the beginning-of-period GDP on the IRF deviation, we find a significantly positive effect as we did in the previous sub-period.

Thus, overall, in both sub-periods there was strong evidence of diversity across the provinces in the way in which they responded to national GDP changes – it is an unacceptable simplification to assume uniformity across the provinces. Furthermore, in both sub-samples it is clear that the greatest improvement in per capita GDP over time was exhibited by those provinces which benefit most from national shocks. There are also considerable differences across the samples; in particular, provinces which do well in the first sub-period are just as likely to do badly as they are to do well in the second.

5.2 A Model with two lags

In the base model we used only one lag in the VAR part of the model as well as in the individual provincial equations. In this sub-section we briefly report the results of extending the number of lags to two. Given our conclusion above that results differ considerably across the two sub-samples, we do not report results for the full sample but focus on the two sub-samples, 1953-1979 and 1980-2010.

With the extension of the model to two lags, the IRFs are no longer monotonic, as expected. However, at the aggregate level, the effect of a unit shock to GDP is positive in both the short and long runs for both sub-samples, with the long-run effect exceeding the short-run effect as before. The individual provincial effects show great diversity as in the one-lag case. Compared to the base case, the provincial GDP effects do not change much in overall magnitude relative to the national effect – in the first sub-sample only one province switched categories between A*/A categories and B/B* and in the second no provinces did. The sign of the slope coefficients in the cross-section regressions were also consistent across the two models.

5.3 Adding a second aggregate variable: investment

There are at least two reasons for extending the model to include two aggregate variables: first to assess whether the effects of a GDP shock are affected by the inclusion of an extra variable and, second, what the effects of a shock to the second variable itself are. The second aim dictates that we use additional aggregate variables which are likely to substantially affect aggregate GDP and we choose four: investment, exports, international trade (exports plus imports) and government expenditure, all of which have been channels through which the national government in China has attempted to boost output. Additionally the choice of these extra aggregate variables allows for a third avenue of research: which of them has the greater effect on output and might, therefore, be the most efficient channel for macroeconomic policy.

Before simulating the effects on the regional outputs of a macroeconomic shock, we need to choose the order of the two variables in the aggregate VAR part of the model. Recall that we orthogonalise the errors in the VAR part of the model by using the Cholesky decomposition of the error covariance matrix, a common procedure but one which has the disadvantage that the results depend on the order in which the variables appear in the model. The implication of the Cholesky approach is that a shock to the first-ordered variable has a contemporaneous effect on both variables while a shock to the second affects only itself within the period. We therefore choose to order the variables as (investment, GDP) since investment, being a component of GDP must necessarily have a contemporaneous effect on GDP but the reverse is not true.

A second choice which needs to be made is that of lag length. We choose this on the basis of criteria applied to the VAR part of the model (even though the same lag length will be applied to all the regional equations as well). Standard criteria have mixed implications. For the first sub-sample they consistently suggest a lag of 1 while for the second sub-sample most criteria point to a lag of 2. We use a common lag of 2 to ensure comparability across sub-samples.

Consider, then, the aggregate and regional effects of a unit shock to GDP in a model which includes investment as an additional aggregate variable. We begin with estimates based on the first sub-sample, 1953-1979. The IRF for aggregate GDP is reported in Figure 5.

[Figure 5 about here]

A comparison to the IRF for the base case in Figure 1 shows that the shapes are very similar. But two differences should be noted; first the wider confidence bounds which reflect both the additional variables as well as the additional lag in the model; second, the long-run multiplier is considerably larger in the two-variable model which reflects the additional expansionary effect through investment – now a boost to GDP has not only subsequent effects through GDP itself but also boosts investment which subsequently boosts GDP.

The effects of the shock on the regional outputs are given in Figure 6.

[Figure 6 near here]

The results in Figure 6 show considerable diversity in the responses of the provinces as was evident in the base case – 6 of the provinces have an IRF which differs significantly from the national IRF, somewhat fewer than in the base model with two lags, due no doubt to the wider confidence bounds about the national IRF. The wide dispersion is also shown in that some of the provincial IRFs are wholly or partly negative although this greater dispersion may result from poorer data quality in the early sub-sample. The pattern of responses differs little from that of the single-variable model with two lags: only one provinces switched between A*/A and B/B* categories according to the summary information reported in Table 5.

[Table 5 near here]

The results for the more recent sub-sample, 1980-2010, are shown in Figure 7 (national) and Figure 8 (provincial) with summary information in Table 5.

[Figures 7 and 8 about here]

In this case the bounds are also quite wide but not as extreme as for the earlier sub-sample. Surprisingly, the long-run effect of the GDP shock is much smaller; in fact, there is little evidence of a multiplier effect at all with the effect of a unit shock being less that 1.2 after 10 years. There is considerably less similarity of the pattern of the results to those both for earlier sub-period and for the single-variable, two-lag case – seven and six of the 28 provinces switched between A*/A and B/B*, respectively. Thus, for this sub-sample the addition of a second aggregate variable has important implications for the effects of an aggregate GDP shock.

We now turn to the second question we can address in a model with two rather than one aggregate variable, namely the effects on provincial GDPs of a shock to the second aggregate variable itself, investment in this case. This is of considerable interest in the Chinese context since, especially early on in the history of the People's Republic of China, investment has been used by the national government as an instrument of macroeconomic policy as well as a means of influencing the regional distribution of output.[7]

[7] See Groenewold *et al.* (2010) for arguments supporting the importance of investment as an instrument used by the central government in China to influence the regional allocation of resources, even after reforms began in the early 1980s.

We choose a shock to investment of a sufficient magnitude to induce a first-period unit increase in aggregate GDP. This ensures comparability between the effects of this shock and those of a unit GDP shock. The IRF for the effect on aggregate GDP of the investment shock for the 1953-1979 period are pictured in Figure 9.

[Figure 9 about here]

It is clear that the confidence bounds are quite wide although they are narrower than for the GDP shock in the same model for the same period. Again, there is a surprising lack of a multiplier effect with the increase in GDP being only 1.2 after 10 years compared to a long-run effect of a GDP shock of about 2.5 for the same period. Perhaps this reflects the inefficiency of investment in the pre-reform period in China; there is considerable evidence that much investment during this period was allocated on the basis of political and national security considerations rather than in an attempt to maximise the productivity of capital.[8]

The regional effects are pictured in Figure 10 and summarised in Table 5.

[Figure 10 near here]

The wide confidence bands mean relatively few significant results in this case (four of the 28 provinces) and the flatter effect is also evident at the provincial level although there are interesting exceptions: Hubei and Niaoning provinces have persistently large effects in excess of 2.5 after 10 years while Guangxi, Yunnan and Gansu have IRFs which closely follow the national lower bound. There is a surprising overall similarity in pattern to the GDP shock in the same model for the same period, as evidenced by the summary information in Table 5 with only two switches between A*/A and B/B*.

The IRF for aggregate GDP for the 1980-2010 sub-sample is shown in Figure 11. The confidence bounds are narrower than for the earlier period, perhaps reflecting the better

[8] See, e.g., Groenewold *et al.* (2008) and references there.

data quality in the later period. Moreover, the long-run multiplier is much greater – an effect of approximately 2.7 after 10 years compared to about 1.2 for the earlier period.

[Figure 11 hear here]

The regional IRFs are presented in Figure 12 and the summary of the patterns in Table 5. The results are less similar to the full sample than those for the earlier sub-sample.

[Figure 12 near here]

The narrower bunds mean that more provinces show more significant diversity – 10 of the 28 provinces have IRFs which are significantly different to those for the nation as a whole. The pattern is very different to that of the earlier period: a total of 14 of the 28 provinces switched between A*/A and B/B* categories as shown in Table 5 suggesting effectively no relationship between patterns in the two sub-samples.

5.4 Adding a second variable: exports

We now consider the effects of adding an alternative second aggregate variable to the model, namely exports. Again, we present results only for the two sub-samples and consider two issues: the influence of the added variable on the effects of a GDP shock and the effects of a shock to the exports variable itself. The effects of a shock to aggregate GDP on aggregate GDP for the earlier sub-sample are represented in Figure 13.

[Figure 13 about here]

The shock is again chosen to ensure a unit effect on GDP in the first period. The IRF has wide confidence bounds as was the case for this sub-sample in the previous simulations so that the cumulative aggregate IRF becomes insignificant between the third and fourth periods after the shock. Similarly, there is almost no multiplier effect with the cumulative IRF being less than 1.2 after 10 periods. This is similar to our findings for investment and may reflect the relative unimportance of exports for the Chinese economy in the early period.

The effects of the aggregate GDP shock on regional outputs is pictured in Figure 14 and the summary information is reported in Table 6.

[Figure 14 and Table 6 near here]

The pattern of responses is similar to that for both the investment shock (two switches) in the previous model and that for the GDP shock in the same model (one switch). Hence, for this sub-sample, whether we add investment or exports as the second aggregate variable seems to make little difference – at the aggregate level the GDP shock has only a small multiplier effect with considerable uncertainty and the pattern of regional effects is very similar in the two cases.

The IRF for the effect on aggregate GDP of the GDP shock in the second sub-sample, 1980-2010 is pictured in Figure 15.

[Figure 15 about here]

The result shows a much narrower confidence band with the IRF still being comfortably significant after 10 years. Moreover, there is also a more marked multiplier effect – at 10 years the accumulated IRF is approximately 1.75. The regional effects are represented in Figure 16 and Table 6.

[Figure 16 near here]

The summary information in Table 6 show that the IRFs have a similar pattern both to the two-variable model with investment and to the single-variable model, both for the 1980-2010 period. Thus, as far as the effects of a GDP shock are concerned, the pattern of regional effects is not much affected by the addition of a second aggregate variable to the model and, if a second variable is added, not much affected by whether that second variable is investment or exports. There are, however, considerable differences between the effects in the two sub-samples, with 10 switches between A*/A and B/B* from 1953-79 to 1980-2010.

Consider now the effects of a shock to the aggregate exports variable itself. The effect on aggregate GDP for the first sub-period is shown in Figure 17.

[Figure 17 near here]

As was the case in the two-variable model with investment, the confidence bounds are wide (the cumulative IRF becomes insignificant between years 3 and 4) but there is a more substantial multiplier effect than was the case for investment: 1.7 or so after 10 years compared to less than 1.2 for investment.

The regional effects are pictured in Figure 18 with summary information reported in Table 6.

[Figure 18 near here]

The wide confidence bounds result in few provincial effects being significantly different from the national IRF with the results for Niaoning being an obvious exception. This is also reflected in the information reported in Table 6 where there are many provinces in the C category and only one in A* and none in B*. Not surprisingly, there are also few switches compared to the investment shock for the same period but this may be as much a function of the considerable uncertainty surrounding the aggregate effects as of the underlying provincial responses as such.

Turning now to the second sub-sample, we represent the IRF for the effect on aggregate GDP of an increase in exports in Figure 19.

[Figure 19 near here]

The bounds are surprisingly wide, especially compared to the investment case where they narrowed in the second half of the sample. There is evidenced of a substantial multiplier effect, however, with the long-run IRF being about 2.5.

The effects of the aggregate export shock on regional outputs is shown in Figure 20, with summary information in Table 6.

[Figure 20 about here]

Despite the wide bounds about the national GDP IRF, there is a surprising number of significant provincial IRFs although most of them are below the lower bounds with many negative through the simulation period. Only two are above the upper bounds for any time: Guangdong and Zhejiang, both coastal provinces. Many are below the lower bound, at least partially and it is interesting that many of these are inland provinces (such as Guizhou, Gansu and Ningxia) as well as north-eastern provinces such as Niaoning and Jilin. The pattern of provincial responses summarised in Table 6 shows considerable differences to previous cases – there were 11 switches form the earlier sub-sample for the same model and 11 switches from the pattern for investment shocks for the same sub-sample.

In addition to exports we also experimented with the use of a trade variable (the sum of exports and imports) as the second aggregate variable in the model. The results are not reported separately since they were very similar for both sub-samples to the results obtained using exports.

5.5 Adding a second variable: government expenditure

Finally, consider the effects of adding a government expenditure variable as the second aggregate variable in the model. Again we ask two questions and report results for two sub-samples. We begin with the question: how are the effects of an aggregate GDP shock affected by the presence of government expenditure in the model? For the first sub-sample, 1953-1979, the aggregate IRF is shown in Figure 21.

[Figure 21 about here]

The bounds are relatively wide although the IRF is significant until about the sixth year. There is a considerable multiplier effect – after 10 years the cumulative IRF for aggregate GDP is about 3, following an initial unit effect.

Regional effects are pictured in Figure 22 and summary information about them is reported in Table 7.

[Figure 22 and Table 7 about here]

In this case Niaoning is dramatically above the upper bound, seemingly benefitting greatly from expansionary fiscal stimulus. Others also above include Henan and Hebei although they are not as dramatic. Still others such as Shandong, Guizhou, Gansu, Shaanxi and Hubei start above the upper bound but seem to lose momentum. Only Jiangsu province is consistently below the lower bound and negative throughout the forecast horizonwhile others such as Ningxia and Jiangxi are partly below. The pattern evident in Table 7 show that there is considerable similarity to the equivalent simulations for the other two models with two aggregate variables – there is one switch compared to the model with exports and two switches compared to the model with investment. So, again, for this sample at least it seems to matter little whether the model is augmented by adding any of the extra variables considered – investment, exports, trade or government expenditure.

The same is true for the second sample; which variable is added changes results little but there is a dramatic change from the first to the second sub-sample. The aggregate IRF is shown in Figure 23.

[Figure 23 about here]

The bounds are relatively narrow with the IRF still significant after 10 years; the multiplier effect is modest at about 1.7 over the same horizon.

The effects of this shock on the provincial outputs a depicted in Figure 24 and their characteristics are summarised in Table 7.

[Figure 24 about here]

There are considerable differences across the two sub-samples – 11 provinces switch between A*/A and B/B* from 1953-79 to 1980-2010. The results are quite similar, however, to those of the previous two models for the same sample period: three and two switches respectively compared to the model with exports and the model with investment as the additional variable. So, again, it appears that the results are far more sensitive to the choice of sample period than to the choice of the second aggregate variable in the model.

The second question we wish to address in the context of this model concerns the effects of shocks to the second variable itself, in this case, government expenditure. Consider the results from the model estimated using data for 1953-79 first. The cumulative IRF for aggregate GDP is shown in Figure 25.

[Figure 25 about here]

Two features of this graph stand out; first, the bounds are very wide, with the effect becoming insignificant before year 3; second, that the long-run effect is smaller than the short-run unit effect imposed by assumption. Thus, it would seem that there is no multiplier effect at all; in fact, the initial effect is lost by about year 4.

These characteristics carry over into the regional effects which are pictured in Figure 26 and summarised in Table 7.

[Figure 26 near here]

The effects for most of the provinces are modest and quite close to those for the nation as a whole. Only Niaoning stands out as a province which exceeds the national response consistently and Gansu is the only one which falls consistently short of the national IRF. This similarity to the national results is borne out in Table 7 which also shows the similarity to the pattern of regional results for the investment and export shocks for the same period with two switches for the former and three for the latter.

Figure 27 graphs the effects on aggregate GDP of a shock to government expenditure for the 1980-2010 sub-sample.

[Figure 27 near here]

Clearly the confidence bounds are wider than in any previous cases, suggesting that government expenditure did not have a discernible and systematic effect on the time path of aggregate output in the second sub-sample. Moreover, the IRF is negative for all horizons except year 1, suggesting a perverse effect of fiscal policy after the (imposed) initial positive effect. The regional effects vary considerably across the provinces. Despite the wide confidence interval about the national IRF, more than half of the provinces have responses significantly different from the national IRF. Some provinces such as Guangdong and Fujian are persistently above the upper limit whereas others are persistently below and therefore persistently negative – Gansu is an example. One province, Inner Mongolia, starts below the lower bound and finishes up above the upper bound .

6. Conclusions

In this paper we have investigated the effects on the provincial outputs in China of shocks to a variety of aggregate variables. We carried out this exercise using a procedure developed by Lastrapes (2005) to assess the effects on individual prices of a shock to aggregate inflation. Models to address this sort of issue quickly run out of degrees of freedom if there are a large number of disaggregated variables (provincial outputs in our case) relative to the number of observations and the Lastrapes procedure resolves this by imposing some restrictions on a VAR model to make estimation and simulation feasible.

We considered five variants of the model depending on the number and identity of the aggregate variables – the disaggregated variables were always provincial GDPs. The first model has just GDP as the aggregate variable and the other four add one aggregate variable in turn: investment, exports, trade and government expenditure. We examined the effects both of GDP shocks as well as shocks to the second aggregate variable.

We found that the effects on the provincial GDPs of an aggregate shock were quite diverse with up to half the provinces' responses being significantly different from the national response. Hence treating the Chinese economy as a uniform whole involves considerable simplification. We began with a sample period of 1953-2010 but found that the results were sensitive to changes in the sample and so presented most estimates for two sub-samples with the break between them set at 1980 to correspond to the beginning of economic reforms in China.

The pattern of the responses of the provinces to an aggregate GDP shock was found not to be very sensitive to the presence or identity of the second variable in the aggregate part of the model. However, the effects of a shock to the second variable depended importantly on the nature of that variable. Interestingly, government expenditure was found to have the smallest effect over time for a given initial shock.

Supplementary cross-section regressions of two types were also carried out. The first addressed the question of whether the effects of an aggregate shock systematically benefitted poor provinces more than rich ones (perhaps as a result of conscious government policy to redress regional disparities) and the second was to address the question of whether provinces which benefitted more than average from aggregate shocks became relatively richer. We found no consistent evidence to support either hypothesis.

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Table 1: Stationarity tests for log provincial real GDP per capita

Province	Level		First difference	
	Intercept	Intercept and trend	No intercept	Intercept
Beijing	0.9810	0.0528	0.0577	0.0000
Tianjin	0.9992	0.8968	0.0464	0.0000
Hebei	1.0000	0.7748	0.0990	0.0001
Guangdong	0.9994	0.7464	0.0008	0.0001
Shandong	1.0000	0.9187	0.0102	0.0000
Fujian	0.9996	0.9009	0.3783	0.0000
Zhejiang	0.9974	0.6506	0.0098	0.0029
Jiangsu	1.0000	0.5212	0.0069	0.0004
Shanghai	0.0792	0.3456	0.0517	0.0000
Niaoning	0.9911	0.6372	0.0561	0.0000
Guangxi	1.0000	0.9991	0.0800	0.0012
Sichuan	0.9999	0.9443	0.0001	0.0000
Guizhou	1.0000	0.9274	0.5563	0.7471
Yunnan	0.9998	0.9466	0.0000	0.0000
Shaanxi	1.0000	0.8934	0.0000	0.0000
Gansu	0.9999	0.4230	0.2961	0.0001
Qinghai	0.9962	0.9789	0.0019	0.0001
Ningxia	1.0000	0.9995	0.7803	0.0059
Xinjiang	0.9909	0.0814	0.3907	0.6333
Shanxi	1.0000	0.9567	0.0000	0.0000
Inner Mongolia	1.0000	0.9926	0.7799	0.8711
Jilin	1.0000	0.9688	0.0000	0.0000
Heilongjiang	1.0000	0.9471	0.3405	0.3690
Anhui	1.0000	0.9805	0.0000	0.0000
Jiangxi	1.0000	0.9877	0.0376	0.0002
Henan	1.0000	0.5700	0.0001	0.0000
Hubei	1.0000	0.9561	0.6884	0.0000
Hunan	1.0000	0.9864	0.2532	0.0000

Values in the cells are marginal probability levels. Tests are based on lags chosen using the SIC criterion with a maximum number of lags of 10. Data from 1953-2010.

Table 2. Stationarity tests for aggregate data

Variable	Level		First difference	
	Intercept	Intercept and trend	No intercept	Intercept
Government expenditure	0.9998	0.9999	0.6943	0.2420
Investment	0.9999	0.0000	0.0456	0.0502
GDP	0.9999	0.8948	0.4113	0.0000

All variables are in log real per capita terms. Values in the cells are marginal probability levels. Tests are based on lags chosen using the SIC criterion with a maximum number of lags of 10. Data from 1953-2010.

Table 3. Impulse responses to a GDP shock and provincial rankings, base model: one aggregate variable (GDP) and one lag

	Rank by Real GDP per capita				**IRF province – IRF national**		
Province	**1953**	**1980**	**2010**	**Mean**	**1953-10**	**1953-79**	**1980-10**
Beijing	3	2	3	2	A*	A*	B*
Tianjin	2	3	2	3	A*	A*	C
Hebei	14	8	11	11	A*	A	A
Guangdong	13	18	12	9	B*	B*	C
Shandong	21	16	9	10	B*	B	C
Fujian	18	19	8	8	A*	C	C
Zhejiang	16	12	6	6	B*	B*	A
Jiangsu	10	11	5	5	B*	B*	A*
Shanghai	1	1	1	1	A	A*	B*
Niaoning	5	4	4	4	A*	A*	A*
Guangxi	27	22	21	24	B*	B*	B*
Sichuan	26	24	25	25	C	B	A*
Guizhou	28	28	28	28	A*	A*	B*
Yunnan	25	26	27	27	B	B	B*
Shaanxi	20	15	15	17	A*	A*	A*
Gansu	12	17	23	20	B*	B*	A
Qinghai	15	7	19	19	B*	B	B
Ningxia	11	6	16	14	B	B	B
Xinjiang	7	14	18	15	B	B	B*
Shanxi	9	10	17	16	A*	A*	B
Inner Mongolia	6	13	7	7	A*	A	B
Jilin	8	9	10	13	A	A	A
Heilongjiang	4	5	13	12	A	A	B*
Anhui	24	27	26	26	B	B	A*
Jiangxi	17	23	22	21	B*	B*	A
Henan	22	25	20	22	A*	A	A
Hubei	19	20	14	18	B	A	A*
Hunan	23	21	24	23	C	C	B

Note: "A" indicates that the provincial IRF is above the national IRF, "B" that it is below and "C" that it is coincident with. An asterisk indicates that the provincial IRF lies outside the bounds of the national IRF for at least part of the projection period.

Table 4. Transition from 1953-1979 to 1980-2010

	A* or A, 1953-79	**C, 1953-1979**	**B or B*, 1953-1979**
A* or A, 1980-2010	7	0	6
C, 1980-2010	1	1	2
B or B*, 1980-2010	6	1	5

Note: "A" indicates that the provincial IRF is above the national IRF, "B" that it is below and "C" that it is coincident with. An asterisk indicates that the provincial IRF lies outside the bounds of the national IRF for at least part of the projection period. The numbers in the cells are the number of provinces which change from the category in the column to that in the row

Table 5. Impulse responses for regional GDP using a model with two aggregate variables (GDP and investment) and two lags

	IRF province – IRF national					
	Shock to GDP			**Shock to Investment**		
Province	**1953-10**	**1953-79**	**1980-10**	**1953-10**	**1953-79**	**1980-10**
Beijing	B*	B*	B*	A*	A*	B*
Tianjin	C	C	C	A	A	B
Hebei	A	A	A	A*	A*	A
Guangdong	A	A	A	B*	B	C
Shandong	A	A	A	A	C	C
Fujian	A	A	A	A	C	C
Zhejiang	A	A	A	B*	B	C
Jiangsu	B	B	B	B*	B*	A*
Shanghai	B*	B*	B*	A	A	B*
Niaoning	A	A	A	A*	A*	A
Guangxi	B*	B*	B*	cross	B	A
Sichuan	A*	A*	A*	B	B	A
Guizhou	A*	A*	A*	A*	A	A
Yunnan	C	C	C	B	B	B
Shaanxi	A	A	A	A*	A	A*
Gansu	A*	A*	A*	B	B	B*
Qinghai	B*	B*	B*	B	B	B*
Ningxia	B*	B*	B*	B*	B	B*
Xinjiang	B*	B*	B*	A	C	B
Shanxi	A	A	A	A*	A	B
Inner Mongolia	A	A	A	A	A	A*
Jilin	C	C	C	C	B	A
Heilongjiang	A	A	A	A	A	B*
Anhui	A	A	A	A	B	A*
Jiangxi	A	A	A	C	B	A
Henan	A*	A*	A*	A	A	B
Hubei	A*	A*	A*	A	B	A
Hunan	A	A	A	A	A	A

Note: "A" indicates that the provincial IRF is above the national IRF, "B" that it is below and "C" that it is coincident with. An asterisk indicates that the provincial IRF lies outside the bounds of the national IRF for at least part of the projection period.

Table 6. Impulse responses for regional GDP using a model with two aggregate variables (GDP and exports) and two lags

	IRF province – IRF national					
	Shock to GDP			**Shock to Exports**		
Province	**1953-10**	**1953-79**	**1980-10**	**1953-10**	**1953-79**	**1980-10**
Beijing	A*	A*	B	C	A	B
Tianjin	A	C	A	A	A	B*
Hebei	A	A	A	A	A	B
Guangdong	B*	B*	B	C	B	A*
Shandong	A	C	A	C	C	B
Fujian	A	C	C	A	C	B
Zhejiang	B*	B	A	C	C	A*
Jiangsu	B*	B	A	B	B	A
Shanghai	A	A	B*	A	A	B
Niaoning	A*	A*	A*	A*	A*	B*
Guangxi	B*	C	B	B	C	B
Sichuan	A	B	A*	B	B	B*
Guizhou	A*	A*	B	A	C	B*
Yunnan	B	B	B	C	C	B
Shaanxi	A*	A*	A*	A	A	B*
Gansu	B	B	A	B	B	B*
Qinghai	B	B	B*	B	C	B*
Ningxia	B	B	B	B	C	B*
Xinjiang	B	A	B*	B	B	C
Shanxi	A*	A*	B	A	A	B
Inner Mongolia	C	C	B*	A	A	A
Jilin	A	C	A	C	C	B*
Heilongjiang	A*	A	Cross	A	A	B
Anhui	A	B	A	B	B	B
Jiangxi	C	B	A	B	B	B
Henan	A	A	A	A	A	B
Hubei	A	A	A*	A	C	B
Hunan	A	A	C	C	C	B

Note: "A" indicates that the provincial IRF is above the national IRF, "B" that it is below and "C" that it is coincident with. An asterisk indicates that the provincial IRF lies outside the bounds of the national IRF for at least part of the projection period.

Table 7. Impulse responses for regional GDP using a model with two aggregate variables (GDP and government expenditure) and two lags

Province	IRF province – IRF national					
	Shock to GDP			Shock to expenditure		
	1953-10	1953-79	1980-10	1953-10	1953-79	1980-10
Beijing	B	C	B*	A*	A*	B
Tianjin	C	A	B*	A*	B	B*
Hebei	A*	A*	A	A	C	B
Guangdong	C	B	B	B*	B*	A*
Shandong	A	A	A	C	C	C
Fujian	A*	B	A	C	C	A*
Zhejiang	B	B*	A*	B*	C	A*
Jiangsu	B*	B*	A*	B*	A	A
Shanghai	C	A	B*	A	A	A
Niaoning	A*	A*	A	A*	A*	B*
Guangxi	B*	B*	B*	B*	C	A*
Sichuan	C	C	A*	A	C	B*
Guizhou	A*	A*	B	A*	A*	B*
Yunnan	B	B*	B	C	C	A
Shaanxi	A	A	A*	A*	A*	C
Gansu	C	A*	B*	B*	B*	B*
Qinghai	B*	B*	B*	A	C	B*
Ningxia	B*	B*	B*	C	C	B*
Xinjiang	B	B	B*	A	C	C
Shanxi	A	A	B	A*	A*	B*
Inner Mongolia	A	A	B*	C	C	cross
Jilin	C	B	C	A	C	B*
Heilongjiang	A	A	B*	A*	C	B
Anhui	A	C	A*	B*	B*	C
Jiangxi	B	B*	A	B*	C	B
Henan	A*	A*	C	A	C	B
Hubei	A*	A*	A*	A	A	B*
Hunan	C	A	C	A	C	B*

Note: "A" indicates that the provincial IRF is above the national IRF, "B" that it is below and "C" that it is coincident with. An asterisk indicates that the provincial IRF lies outside the bounds of the national IRF for at least part of the projection period.

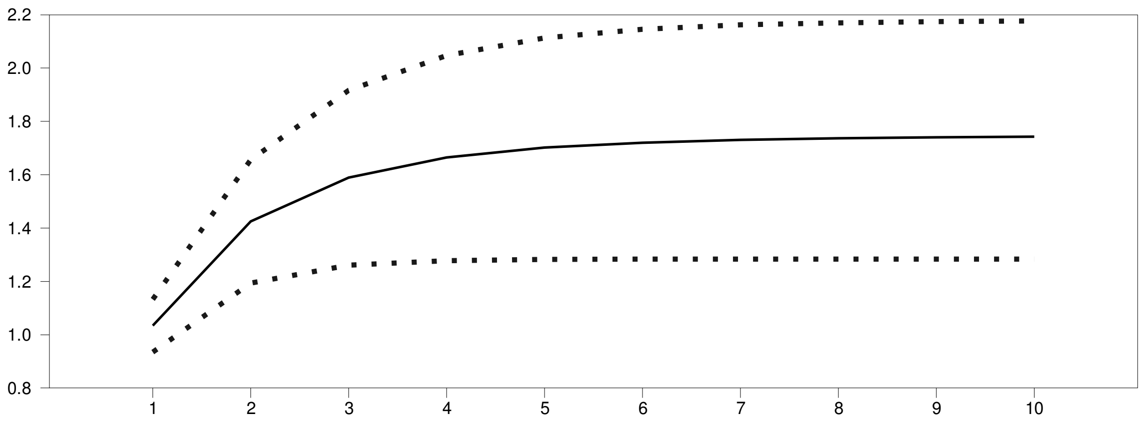


Figure 1. IRF for effect on GDP of a unit shock to GDP; single-variable model with one lag; sample 1953-2010.

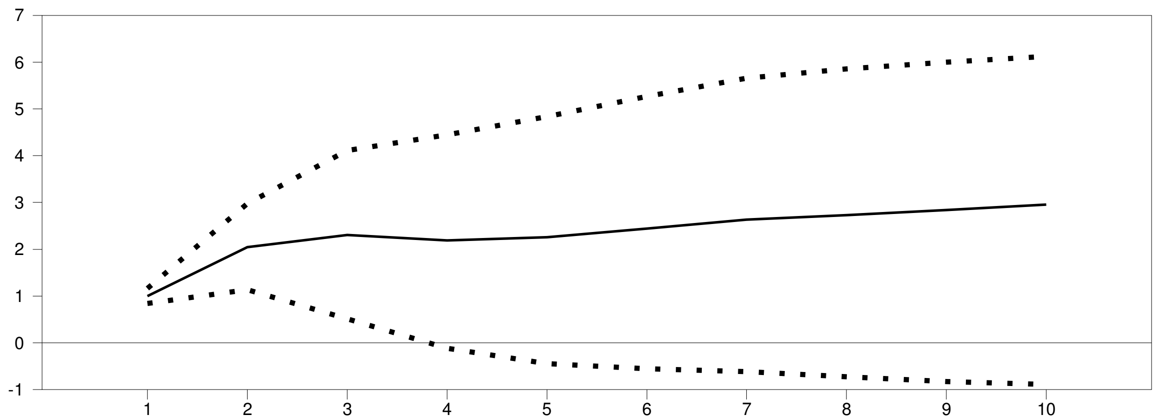


Figure 5. The IRF for the effect on GDP of a unit shock to GDP; two-variable model with investment; sample 1953-1979.

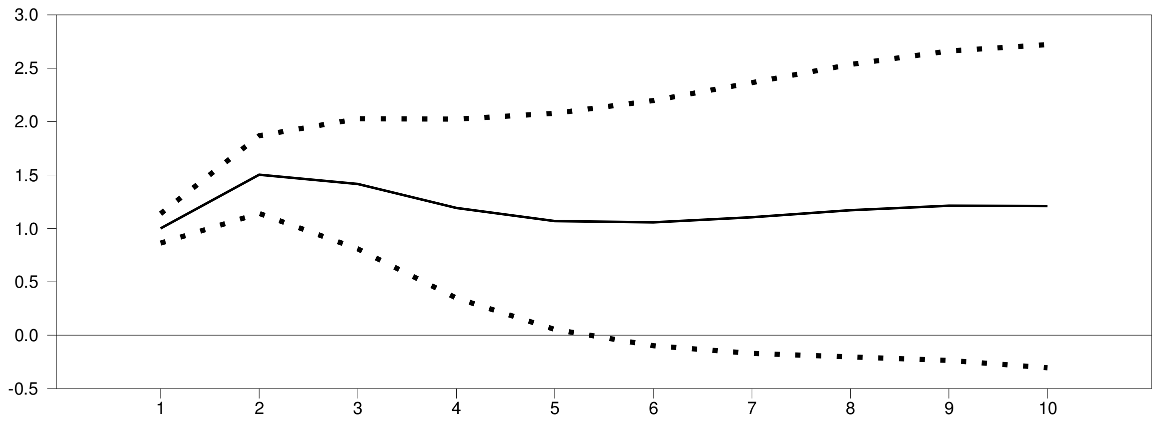


Figure 7. The IRF for the effect on GDP of a unit shock to GDP; two-variable model with investment; sample 1980-2010.

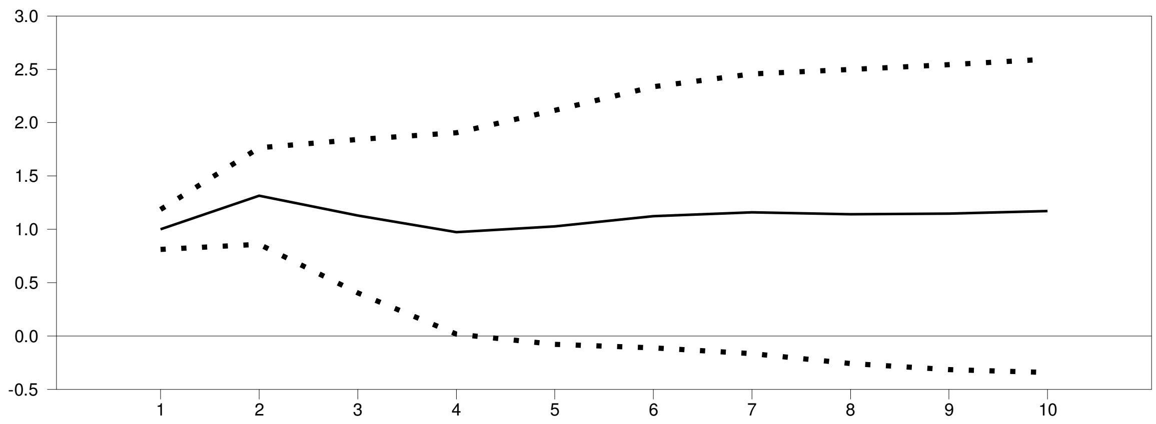


Figure 9. The IRF for the effect on GDP of a shock to investment; two-variable model with investment; sample 1953-1979.

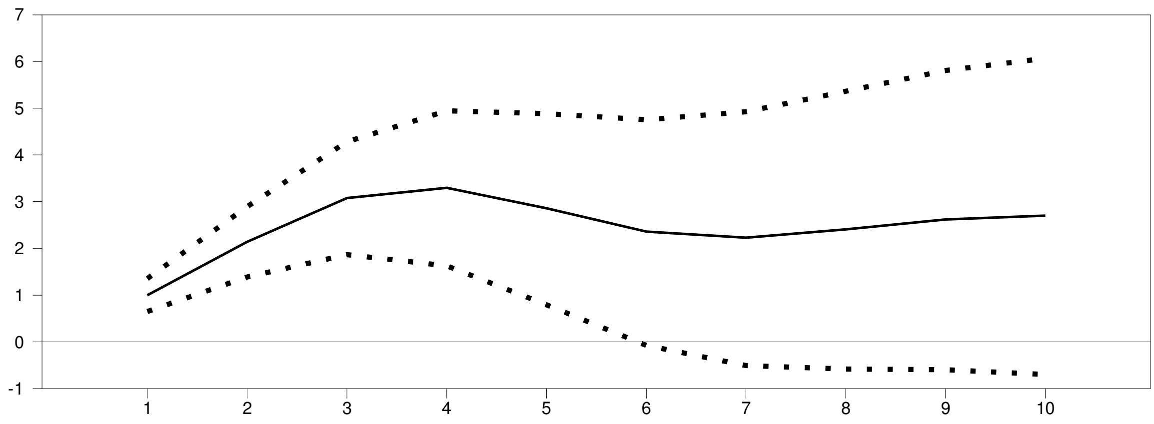


Figure 11. The IRF for the effect on GDP of a shock to investment; two-variable model with investment; sample 1980-2010.

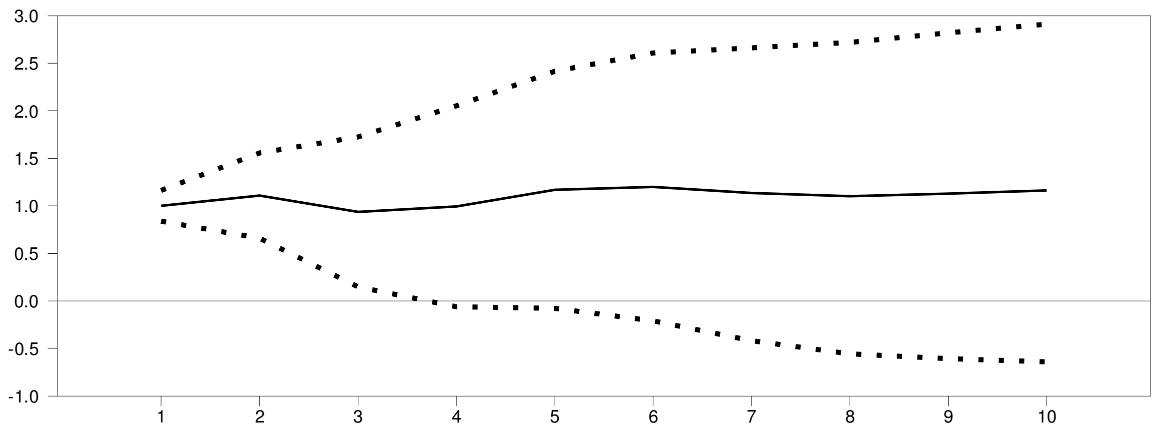


Figure 13. The IRF for the effect on GDP of a unit shock to GDP; two-variable model with exports; sample 1953-1979.

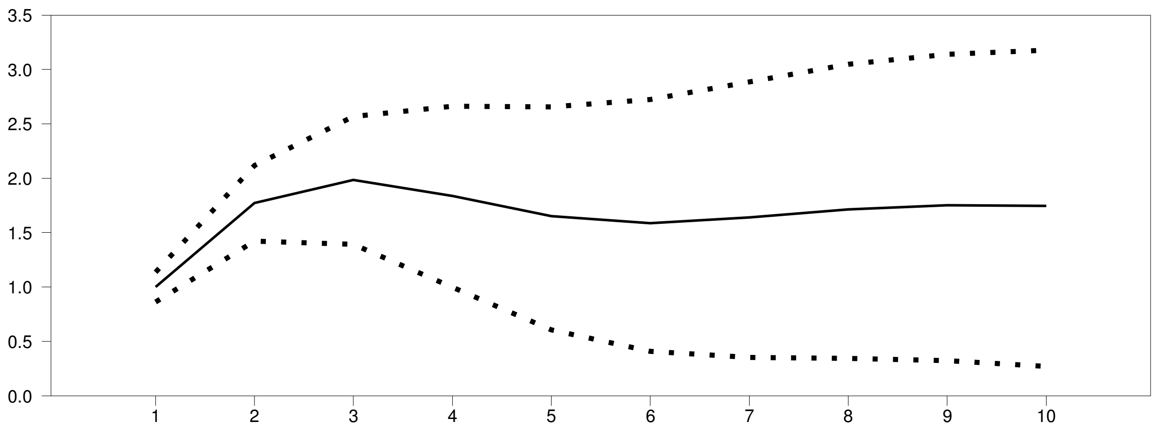


Figure 15. The IRF for the effect on GDP of a unit shock to GDP; two-variable model with exports; sample 1980-2010.

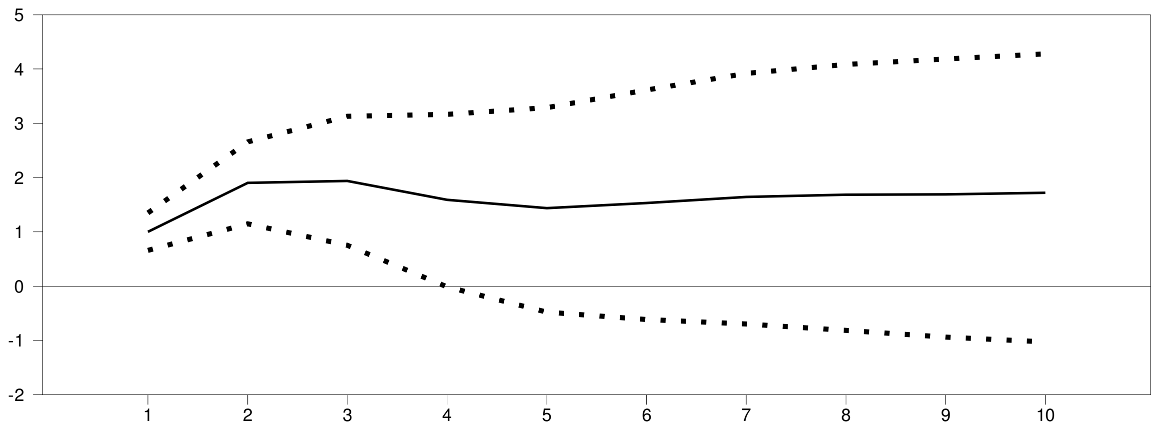


Figure 17. The IRF for the effect on GDP of a shock to exports; two-variable model with investment; sample 1953-1979.

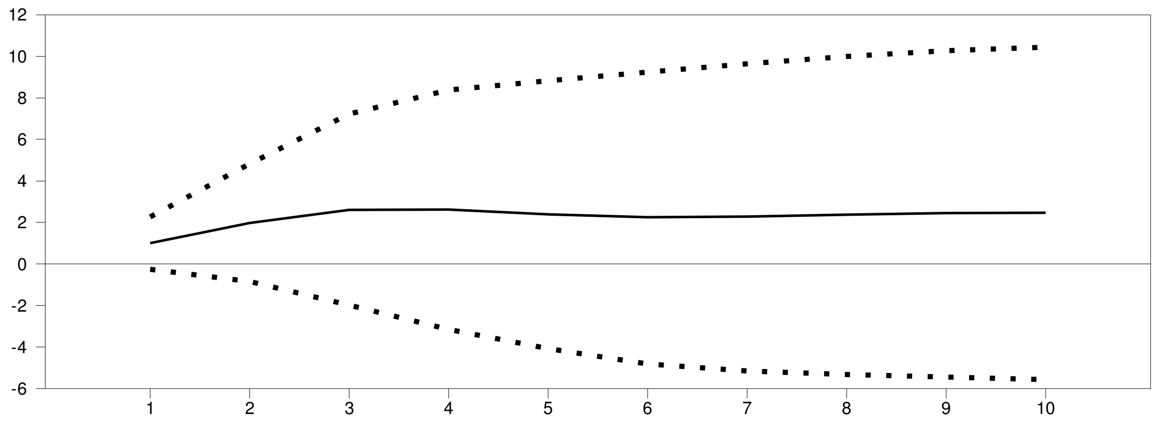


Figure 19. The IRF for the effect on GDP of a shock to exports; two-variable model with investment; sample 1980-2010.

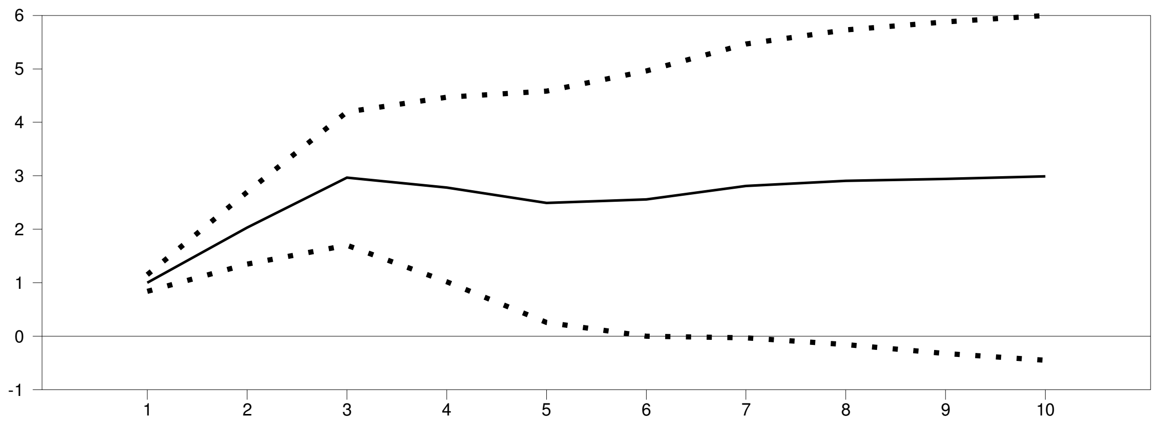


Figure 21. The IRF for the effect on GDP of a unit shock to GDP; two-variable model with government expenditure; sample 1953-1979.

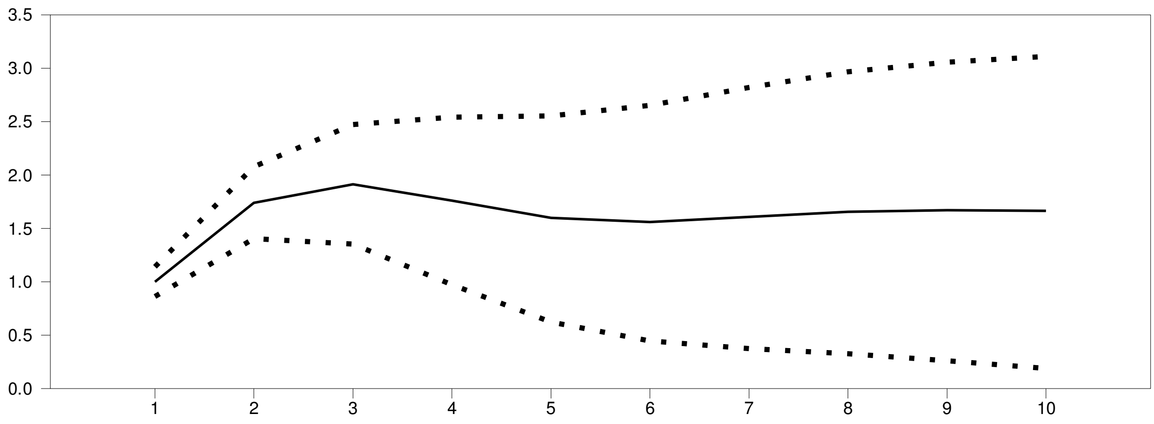


Figure 23. The IRF for the effect on GDP of a unit shock to GDP; two-variable model with government expenditure; sample 1980-2010

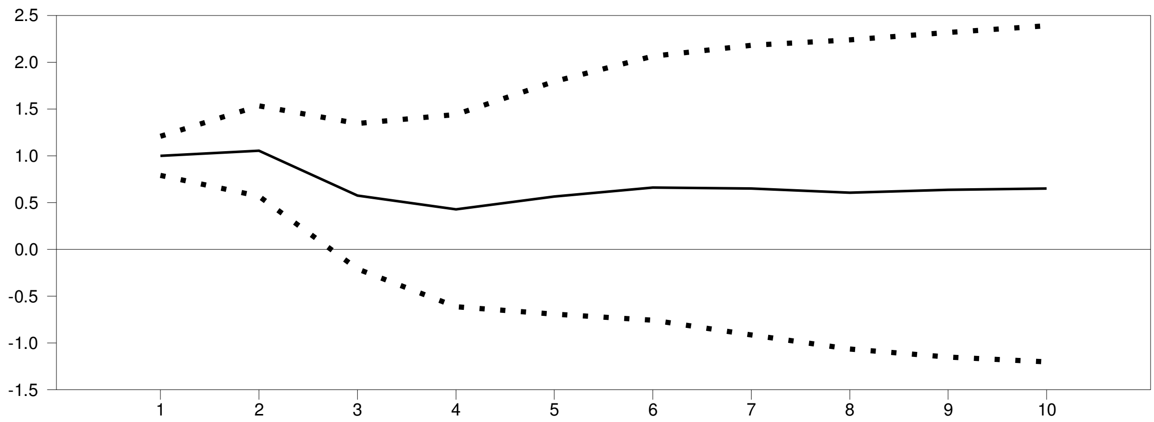


Figure 25. The IRF for the effect on GDP of a shock to government expenditure; two-variable model with government expenditure; sample 1953-1979.

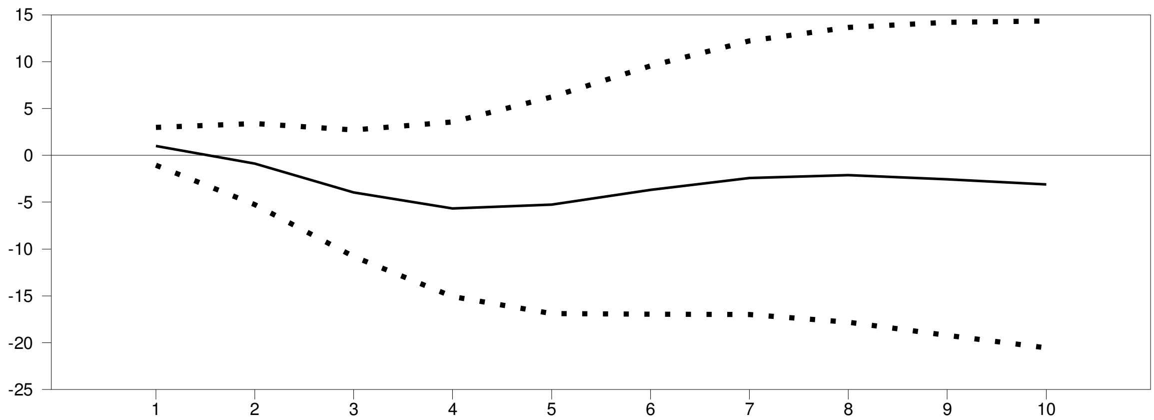


Figure 27. The IRF for the effect on GDP of a shock to government expenditure; two-variable model with investment; sample 1980-2010.

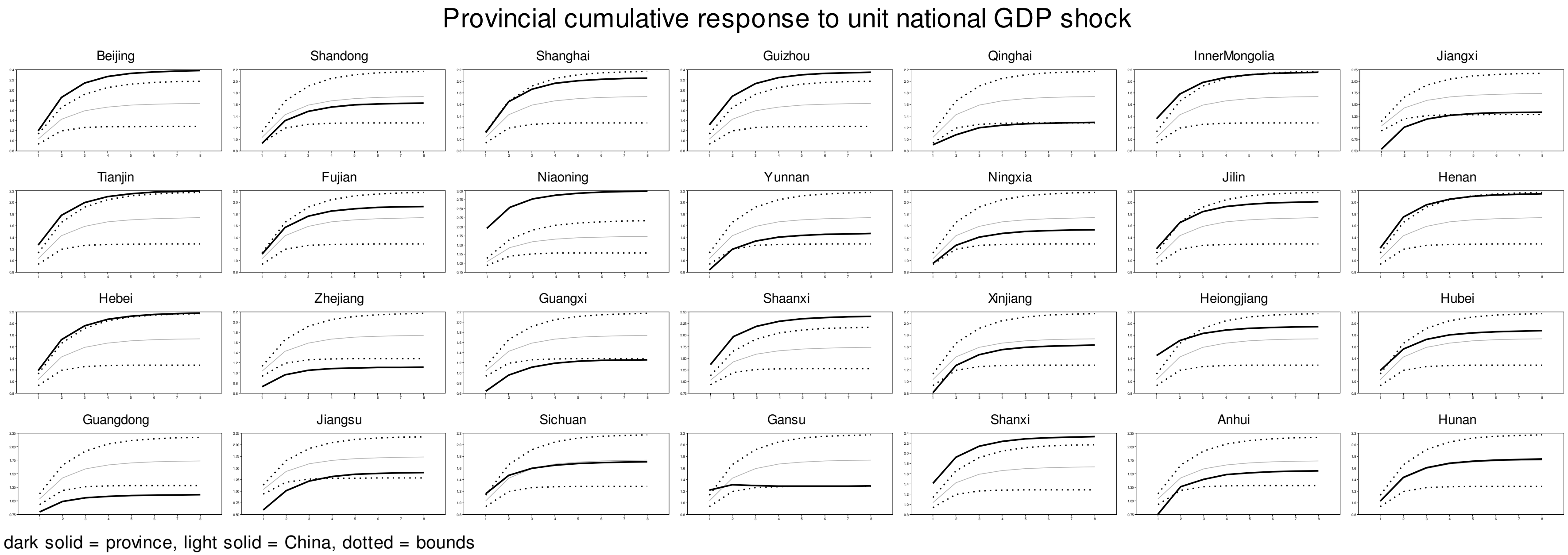


Figure 2. Effects on provincial GDP of a unit shock to aggregate GDP, sample 1953-2010

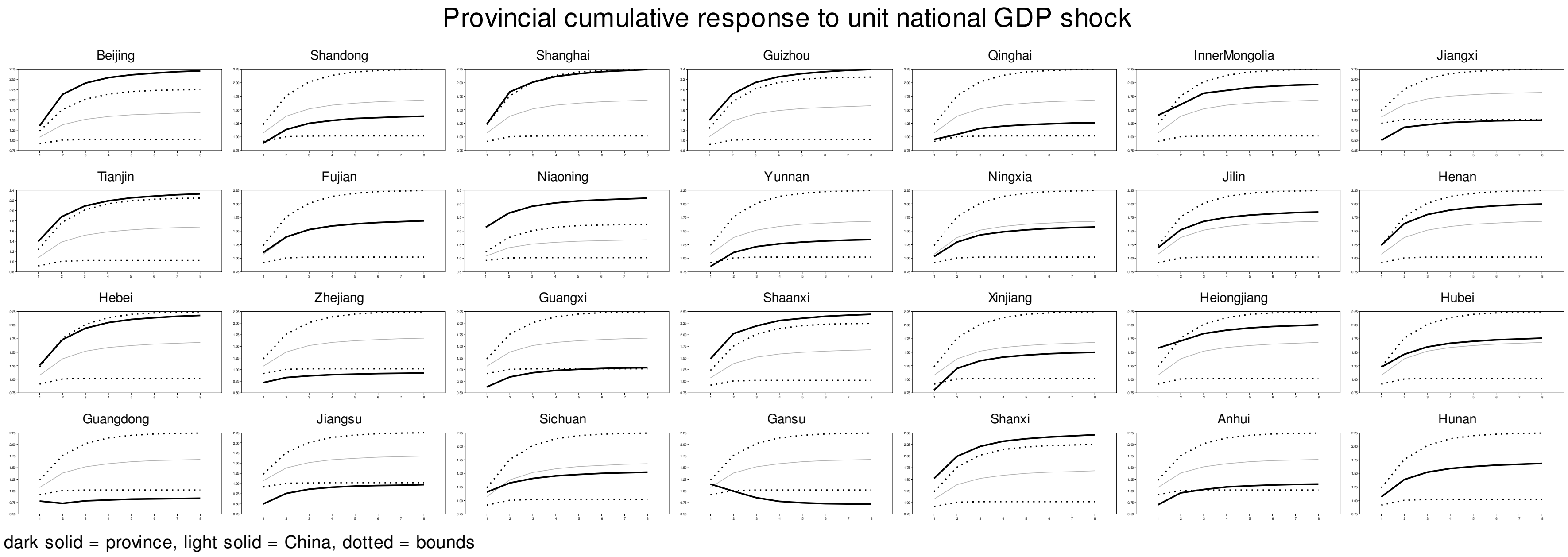


Figure 3. Effects on provincial GDP of a unit shock to aggregate GDP, sample 1953-1979

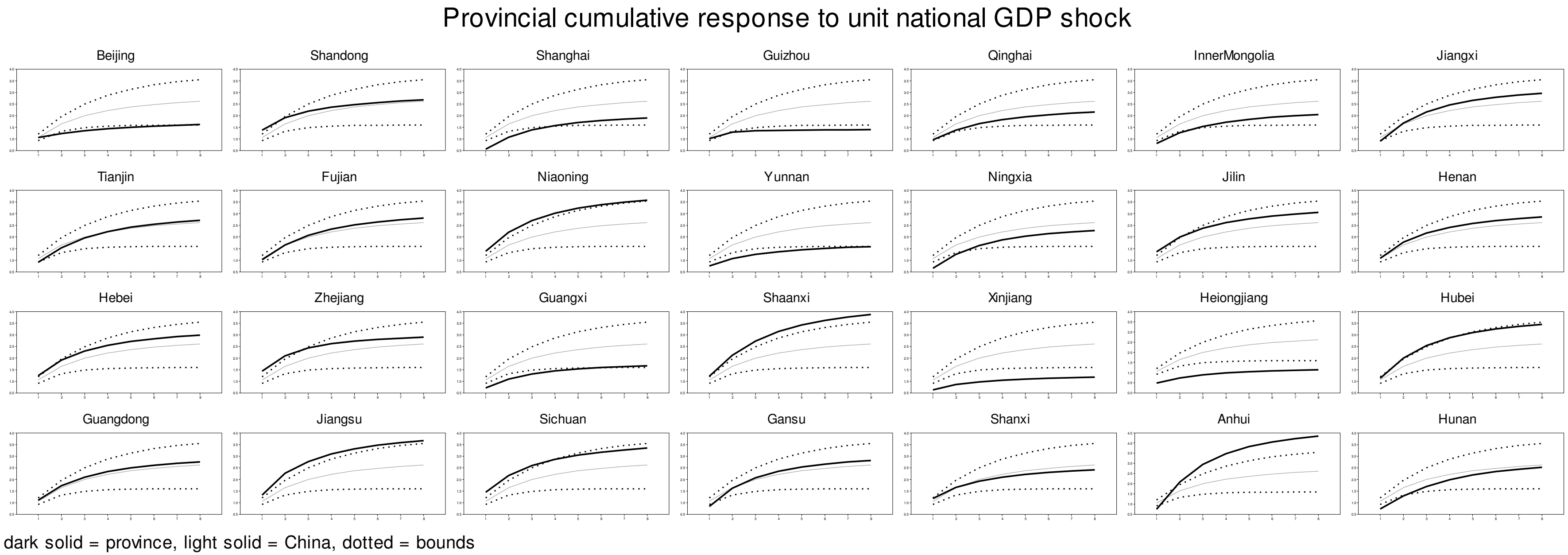
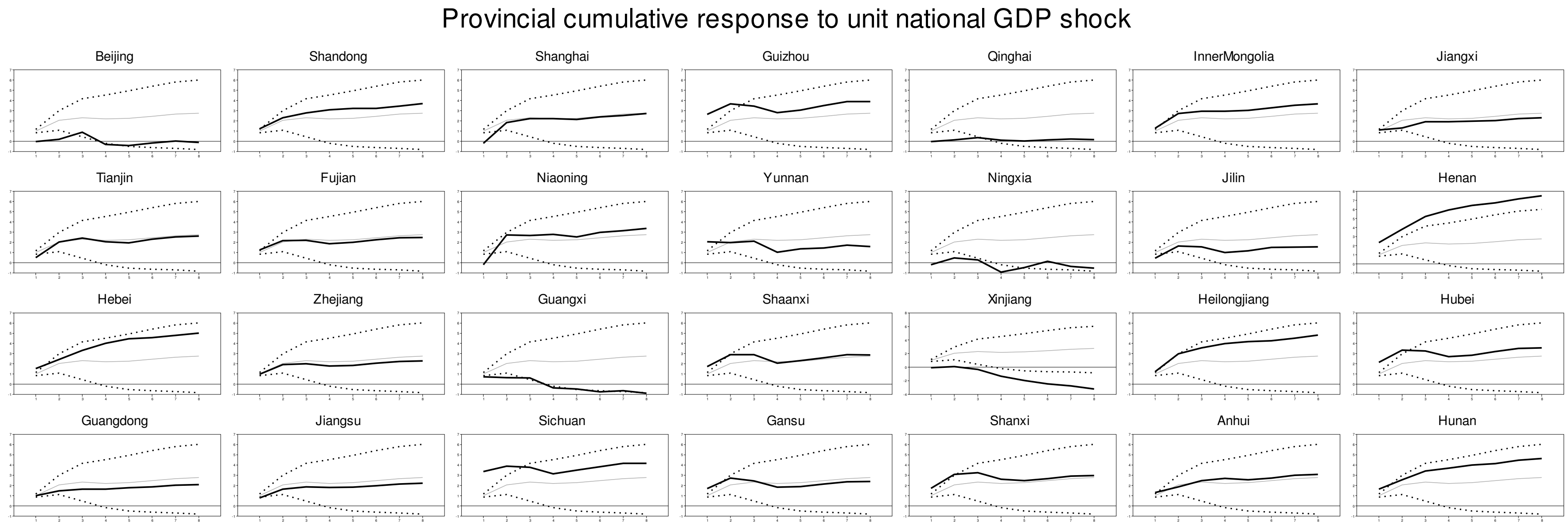


Figure 4. Effects on provincial GDP of a unit shock to aggregate GDP, sample 1980-2010



dark solid = province, light solid = China, dotted = bounds

Figure 6. Effects on provincial GDP of a unit shock to national GDP in a model with investment, sample 1953-1979

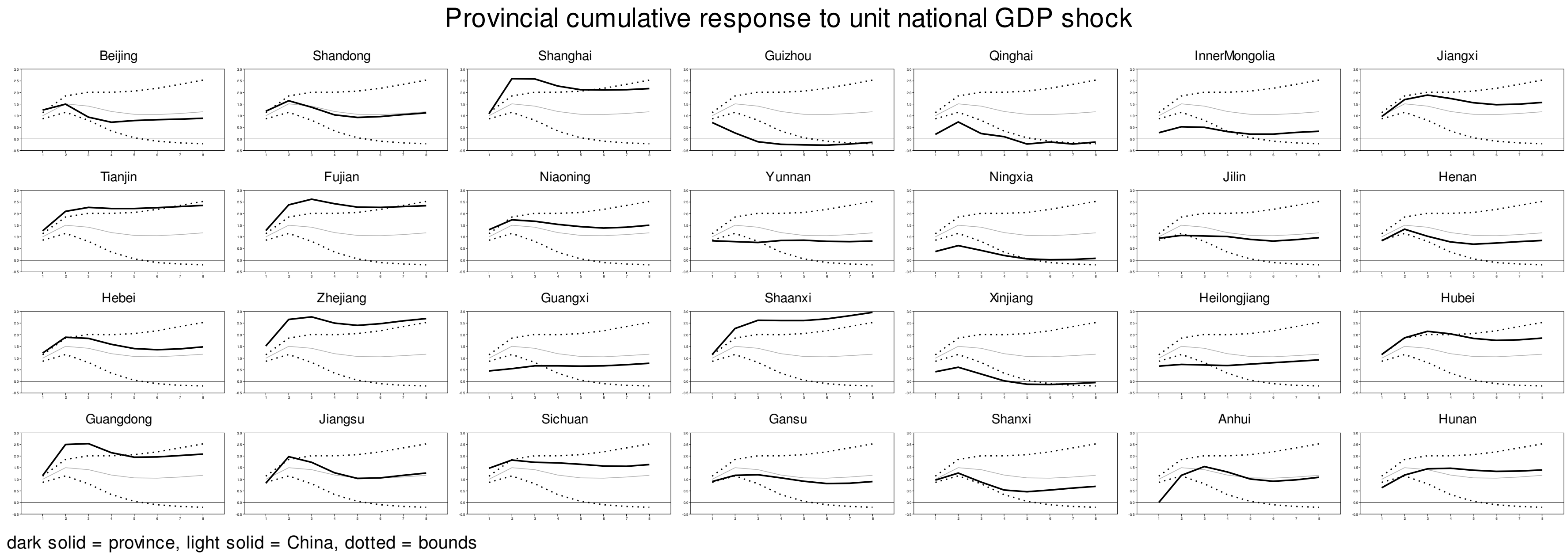


Figure 8. Effects on provincial GDP of a unit shock to national GDP in a model with investment, sample 1980-2010

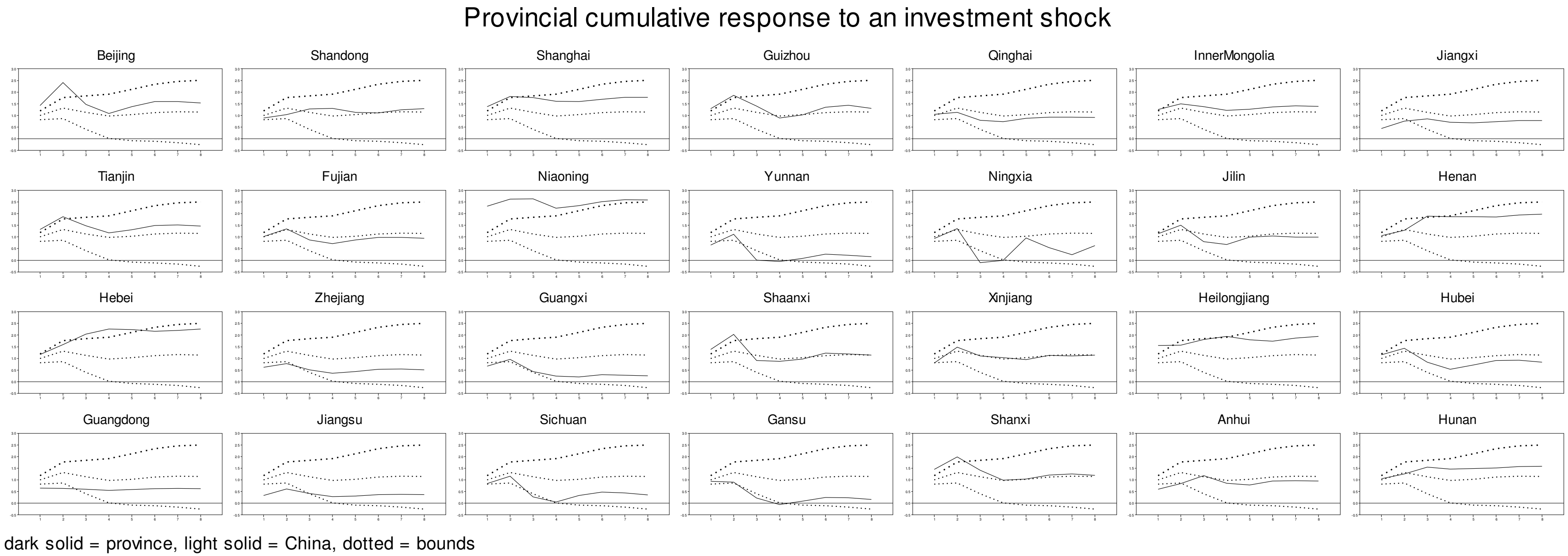


Figure 10. Effects on provincial GDP of an investment shock in a two-variable model (GDP and investment), sample 1953-1979

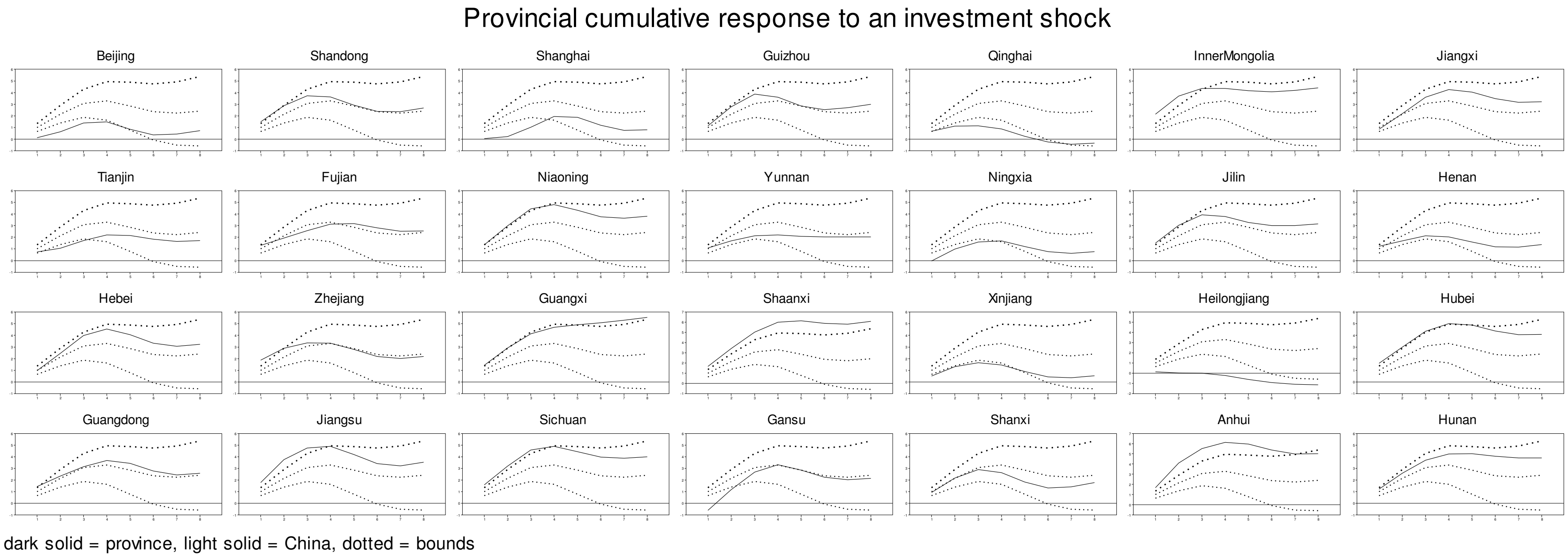


Figure 12. Effects on provincial GDP of an investment shock in a two-variable model (GDP and investment), sample 1980-2010

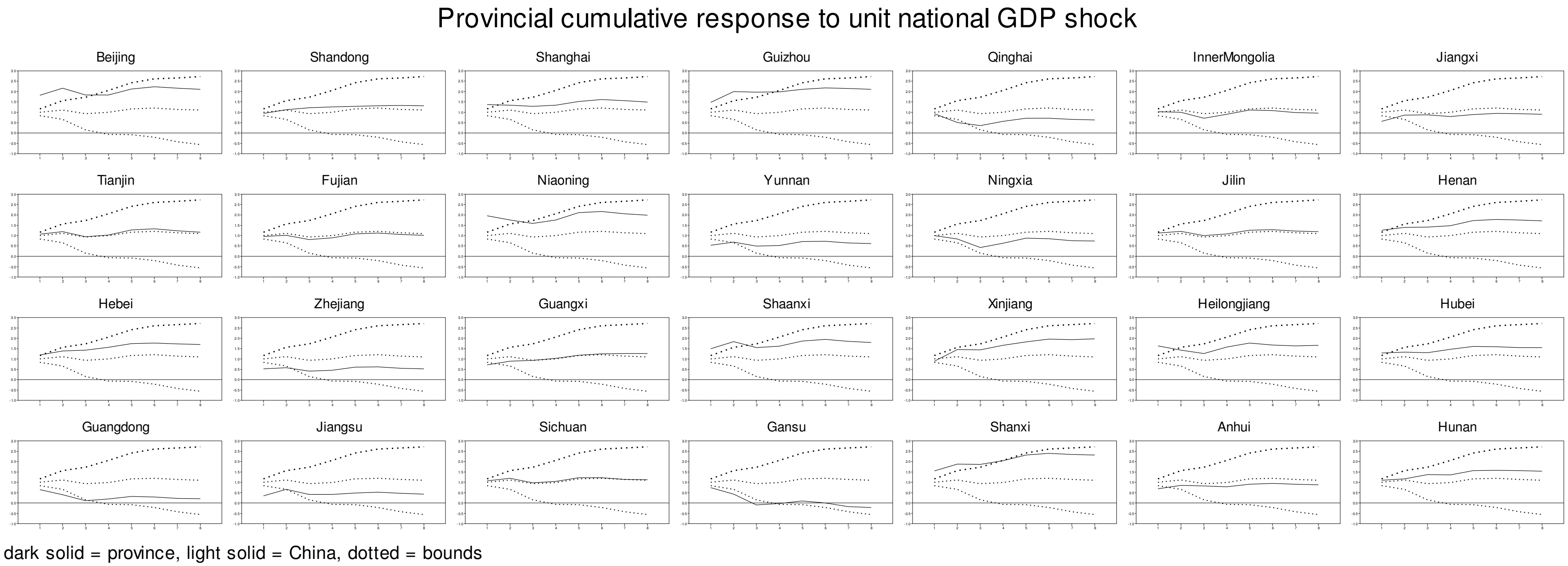


Figure 14. Effects on provincial GDP of a GDP shock in a two-variable model (GDP and exports), sample 1953-1979

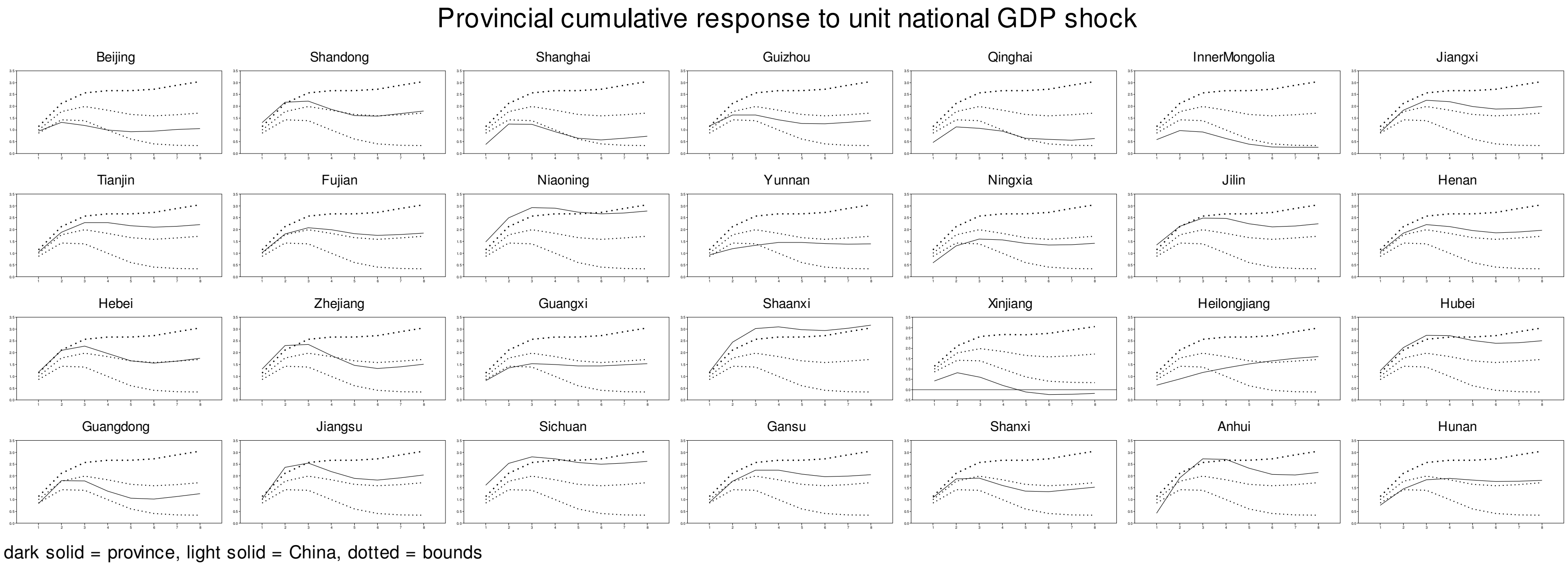


Figure 16. Effects on provincial GDP of a GDP shock in a two-variable model (GDP and exports), sample 1980-2010

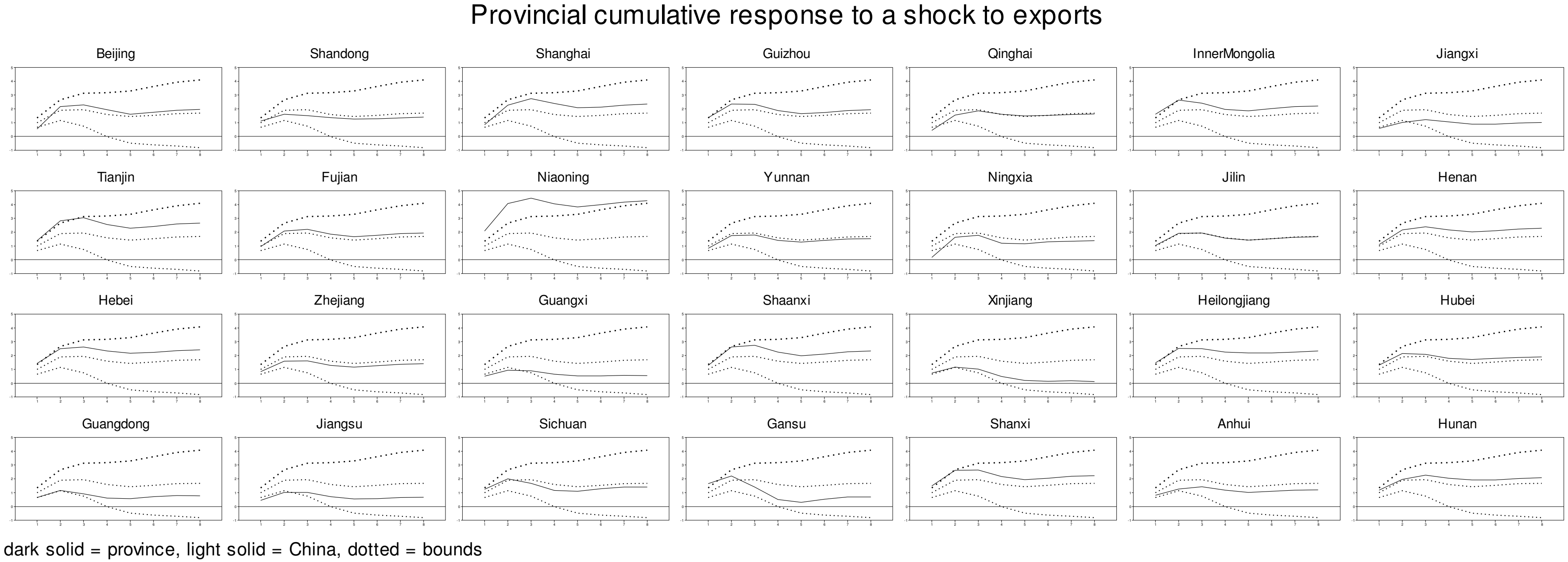


Figure 18. Effects on provincial GDP of an exports shock in a two-variable model (GDP and exports), sample 1953-1979

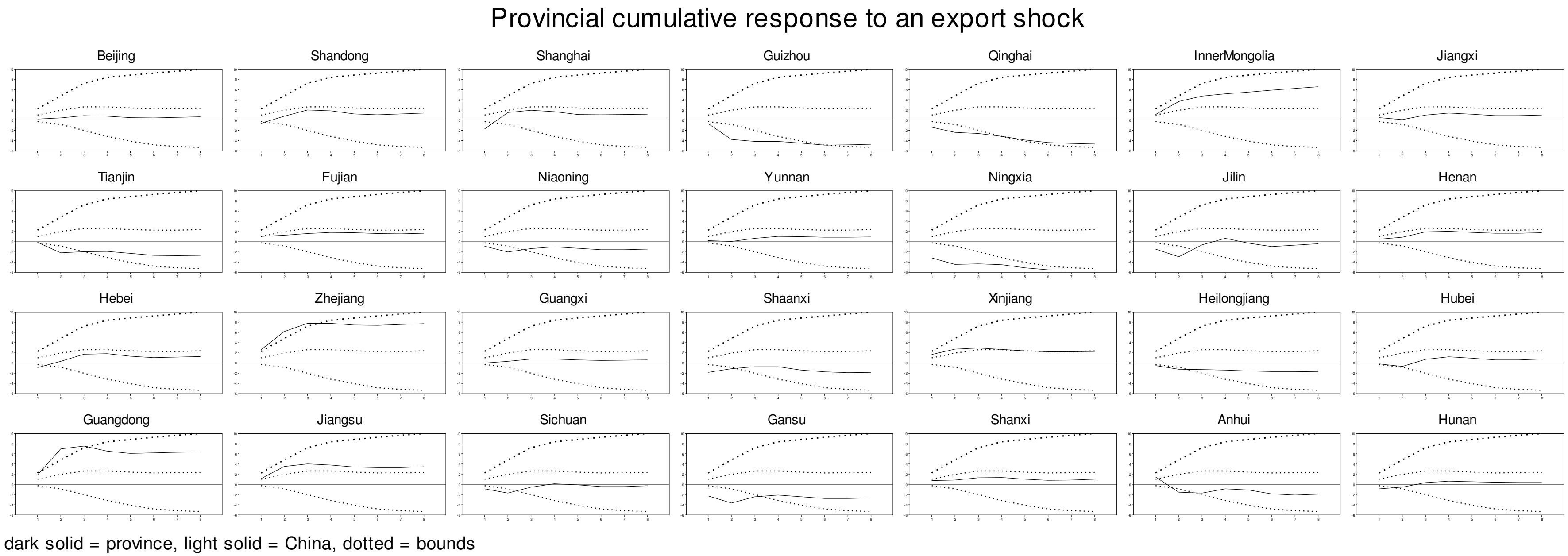


Figure 20. Effects on provincial GDP of an exports shock in a two-variable model (GDP and exports), sample 1980-2010

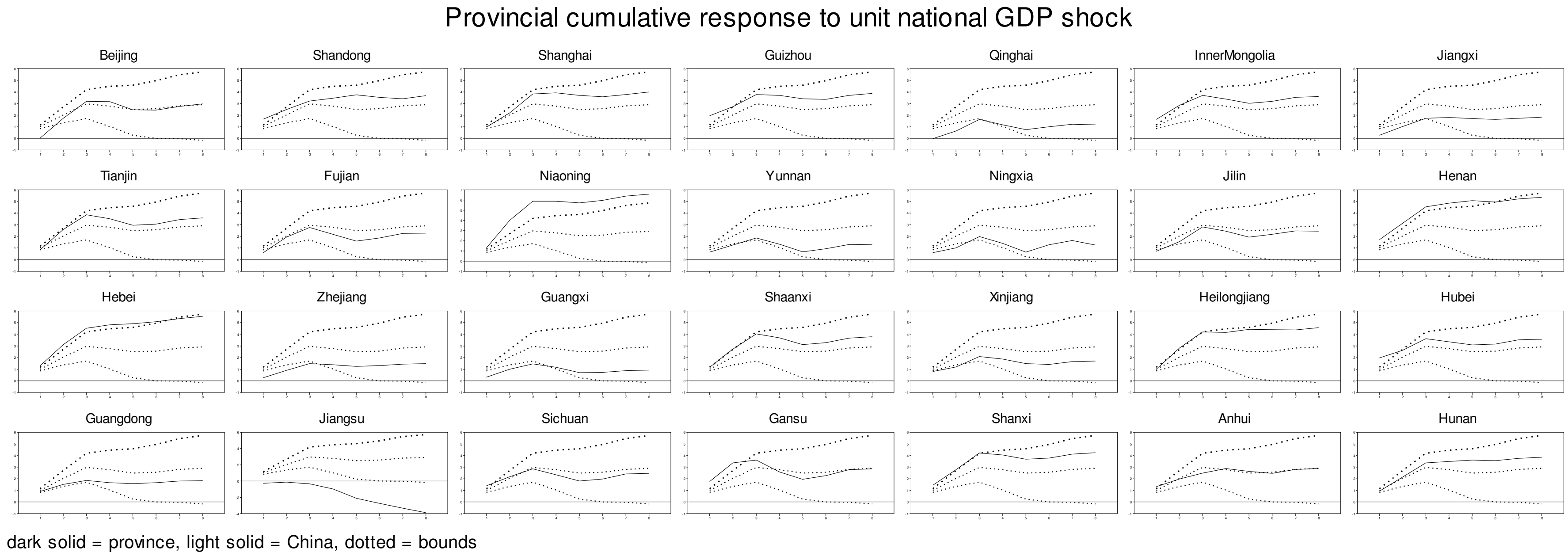


Figure 22. Effects on provincial GDP of a GDP shock in a two-variable model (GDP and government expenditure), sample 1953-1979

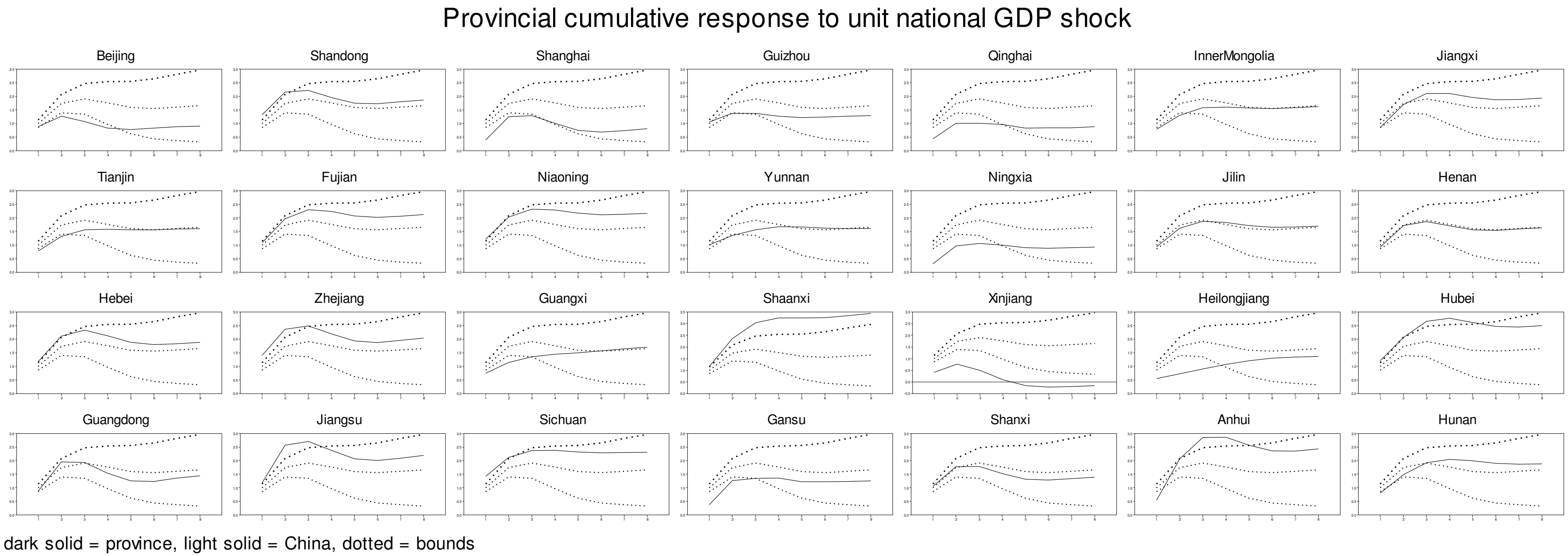


Figure 24. Effects on provincial GDP of a GDP shock in a two-variable model (GDP and government expenditure), sample 1980-2010

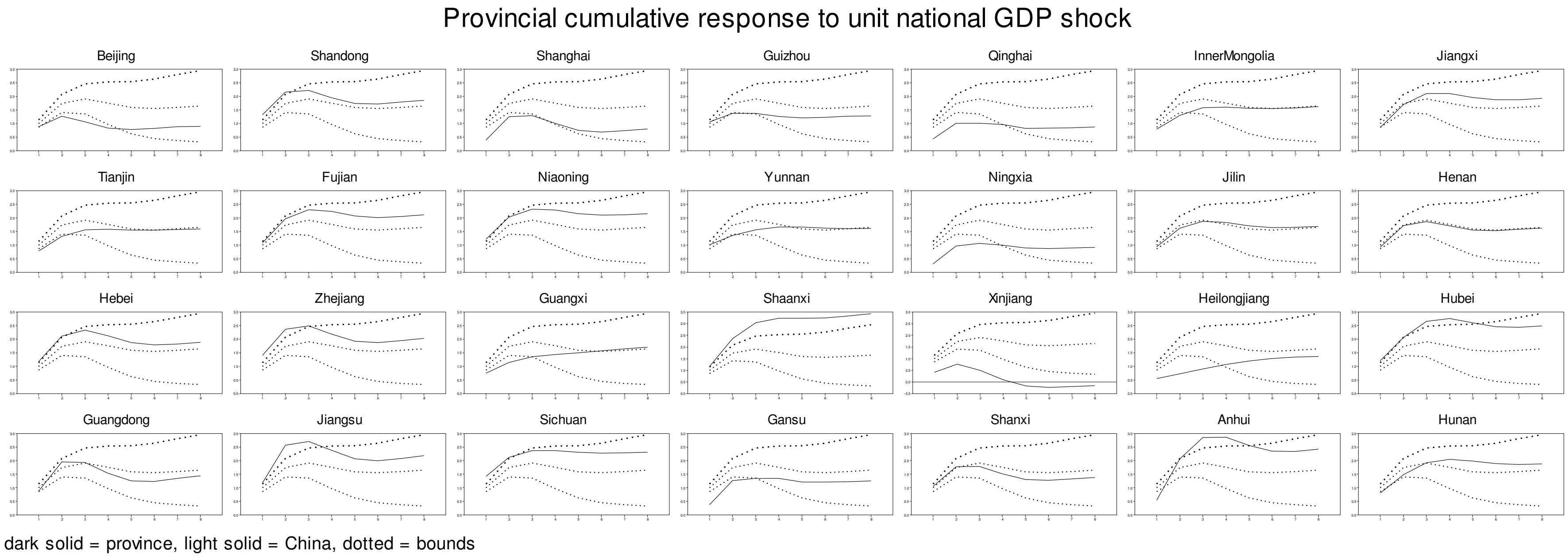


Figure 26. Effects on provincial GDP of a shock to government expenditure in a two-variable model (GDP and government expenditure), sample 1953-1979

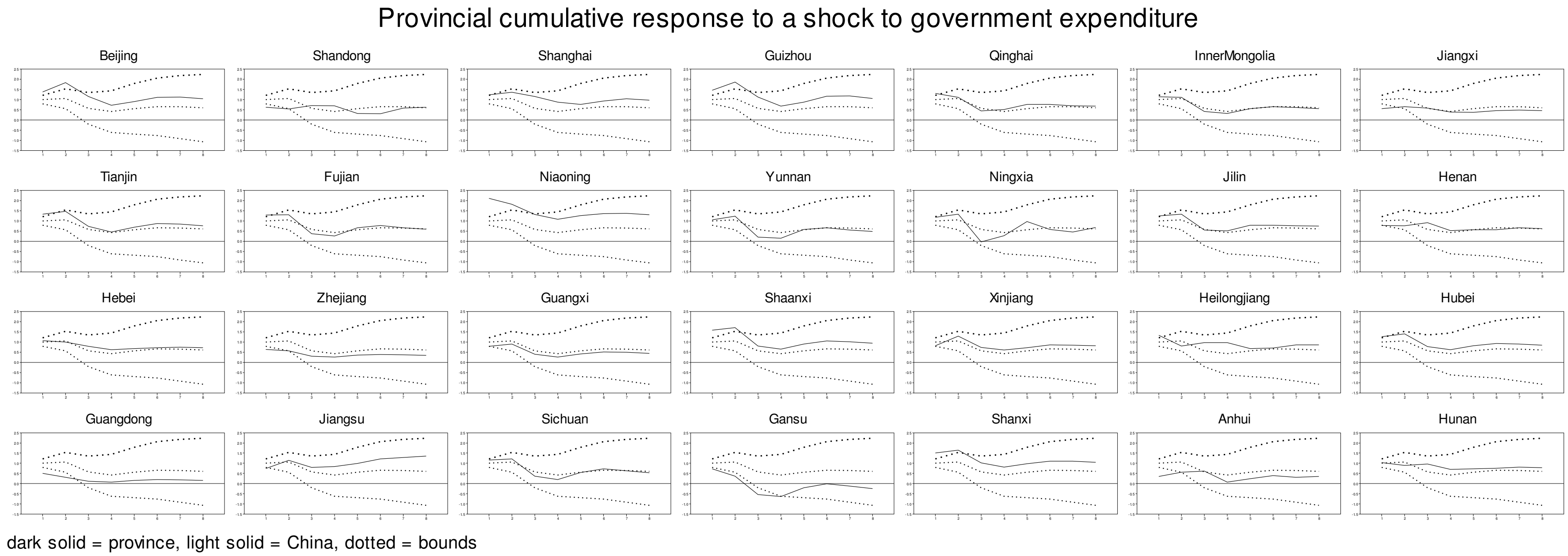


Figure 28. Effects on provincial GDP of a shock to government expenditure in a two-variable model (GDP and government expenditure), sample 1980-2010