Inter-Regional Spillovers in China: The Importance of Common Shocks and the
Definition of the Regions

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Abstract:

This paper examines the question of inter-regional spillovers in China. We argue that this is a central question in Chinese economic policy, given the marked regional disparities that exist and the concern of policy-makers to ameliorate them.

We analyse this question within the framework of a six-region vector-autoregressive model which we subject to extensive sensitivity analysis, with particular attention paid to the effects on the results of strong common output movements. We find the results of dynamic simulations to be importantly dependent on model specification; in particular, they are sensitive to the order in which the variables enter the model. After an assessment of various alternatives, we are able to specify a model with tolerable robustness by using data which has been purged of the effects of national output fluctuations. We find some expected but also some unexpected results. In the first category, the Yellow River and Changjiang River regions are found to have spillover effects on other regions although they are more extensive for the former; the South Western region has no significant spillover effects on the rest of the country, consistently with the results of previous research. However, in contrast both to other research and to our expectations, shocks to the South Eastern region affect mainly the region itself with little spillover to the other regions. The same is true of the North East region while the North West region has extensive spillovers to other regions. We conclude that there is still much to be learned about the magnitude and timing of inter-regional spillovers before firm policy conclusions can be drawn.

1. Introduction

China's emergence as a major player in the world economy in the last 25 years has been impressive and seemingly inexorable. Between the beginning of economic reforms in 1978 and 2003 the average rate of growth of real GDP has been about 10% per annum; this is an outstanding record, even by the standards of the rapid growth experienced by many countries in the region in the last quarter of the 20th century.

This rapid growth has, however, been far from smooth – it has fluctuated wildly over time and it has been very uneven across the country. Growth in the often tumultuous pre-reform years fell as low as -27.3% in 1961 as a result of the disastrous Great Leap Forward from a high of 21.3% in 1958. Even the post-1978 period has seen substantial, albeit smaller, fluctuations in the range of 3-15% per annum.

Growth has not only fluctuated over time but the spatial distribution has also been far from uniform. In the post-1978 period the average annual growth rate has varied from a low of 7.6% for Qinghai province in the north-west of China to rates over 13% for the south coastal provinces of Zhejiang, Fujian and Guangdong. Of greater concern than the differences in growth rates is the fact that, by and large, these differences have exacerbated already large disparities in output levels.

Not surprisingly, the spatial distribution of economic activity and welfare has been the subject of considerable interest to both policy-makers and academic researchers.

From the beginning of the People's Republic of China the authorities have shown an awareness of and concern for the effects of persistent regional economic disparities. Early in the post-war period, particularly during the first two Five-Year Plans (1953-57, 1958-62), the Chinese government emphasised industrialisation in general and initially favoured the north-eastern provinces which already had a relatively advanced industrial structure in 1949.¹ However, at least from the Third Five-Year Plan covering 1966-1970, there has been a major focus on regional differences in economic policy formulation. As a result of the worsening relationships with the Soviet Union at that time, there were serious concerns for national security of inland China which, coupled with a focus on Mao's principle of industrial self-sufficiency, resulted in a strong bias in the allocation of public investment funds in favour of western and central regions at the expense of the more

¹ This region, formerly Manchuria, was occupied by the Japanese in the decade prior to the end of World War II and there is some argument that this contributed to the development during this period (see, e.g., Demurger *et al.*, 2002) although this issue is controversial.

prosperous coastal region. Investment allocated to interior provinces increased to 71%.

Emphasis began to shift, however, in the early 1970s with China's greater interaction with western economies and there was a gradual redirection of investment from the west to the other regions. In the Fifth Five-Year Plan (1976-1980) there was a shift of focus back to the coast with the share of investment going to the coastal provinces being the highest since 1952; not surprisingly, growth in the coast began to outstrip that in the rest of the country. By the Sixth Five-Year Plan (1981-1985) there was an explicit policy of unbalanced growth, now favouring the coastal region. This policy of unbalanced growth continued during the currency of the Seventh Five-Year Plan (1986-1990) with an even higher proportion of government investment going to coastal provinces compared to the interior provinces.

This redirection of capital to the already fast-growing coastal provinces was based on the argument that the development resources of the country should be allocated to those regions likely to benefit most in terms of growth and the expectation that fast-growing coastal regions would act as a growth locomotive, taking the rest of the country with it.

More recent Plans have shifted the focus back towards the interior with growing concern about the implications for social instability of large and persistent differences in inter-provincial levels of economic welfare. In particular, in 1999 the central government announced the Great Western Experiment during the currency of the Ninth Five-Year Plan in which considerable shifts of resources to the western provinces were foreshadowed.²

Notwithstanding the more recent shift in regional focus, there continues to be an expectation that the faster-growing coastal region will exert a beneficial influence on the remaining regions. This expectation depends on the existence of strong economic linkages between regions. While there has been much discussion of these inter-regional real output spillovers, there is remarkably little empirical work assessing their strength and timing, notwithstanding the large empirical literature on Chinese regional economic growth. Indeed, there are, to our knowledge, only four papers which directly address the question of regional spillovers in China – Ying

² As it turned out, investment in both central and western regions increased more rapidly than that in the coastal region from 1999 to 2002 but fell back in 2003; the ratio of central to coastal values for total investment in fixed assets rose steadily from 36.7% in 1999 to 40.3% in 2002 but fell back to 38.7% in 2003. Similar figures for the western region are 25.5% in 1999, 28.3% in 2002 and 26.5% in 2003.

(2000), Zhang and Felmingham (2002), Brun, Combes and Renard (2002) and Groenewold, Lee and Chen (2005).

We will argue that much work needs to be done before we have clear answers to the question of whether and how output changes in one region influence output in other regions. It is the aim of this paper to contribute to the limited literature in this area by extending the work of Groenewold *et al.* They use a vector-autoregressive (VAR) model with three regions as a framework for dynamic simulation of the effects of a shock to one region on the other two regions. While their analysis is interesting and informative, it is limited in that it uses only three regions and in the absence of sensitivity analysis.

While the three-region grouping used in Groenewold *et al.* is a standard regional grouping for China and one that is widely used in both empirical work and policy discussion (see, e.g., Yao and Zhang 2001a, 2001b, Brun *et al.* 2002, Bao *et al.* 2002, Zhang and Felmingham, 2002, Liu and Wei, 2003, and Wu, 2004), it is by no means the only possible one.³ As with all regional aggregations, there will be disparities of economic structure within the region on the one hand and similarities across regions on the other. Given the diversity of the Chinese economy this will be a particularly important issue here. In the absence of a clearly optimal regional aggregation, it is important to assess the sensitivity of the results to the regional definition used. In this spirit, our first objective in this paper is to assess the sensitivity of their results to an alternative, recently suggested, less aggregated regional grouping of the provinces. An added benefit of the use of smaller regions is that the widening of the number of regions will also provide further insight into what happens inside the broader regions, thus allowing the formulation of more nuanced policy conclusions.

Our second contribution is indirectly related to the use of smaller regions. It is one of the well-known properties of the VAR model that its simulations may be sensitive to the order in which the variables appear in the model. Groenewold *et al.* present results based on only one regional ordering, viz. coastal, central and western. While this is a natural one for three regions, it is more difficult to argue for a natural ordering of six regions so that an assessment of the sensitivity of results to the

³ Note that while the three-region disaggregation is common, the exact definition of each of the regions may differ slightly in different cases; thus, e.g., Zhang and Felmingham (2002) include Guangxi in the central region whereas others allocate it to the coastal region.

initially-chosen ordering is more urgent than it is in the three-region case. We carry out such sensitivity analysis for our initial choice of regions and find extreme sensitivity. This motivates us to explore various means of reducing the common correlation which underlies this “sensitivity problem”. We propose a preferred method and conclude that we are able, using this method, to be more confident about our results.

The remainder of the paper is structured as follows. Section 2 places our work in its context by providing a brief review of the literature, both on inter-regional spillovers and that relating to the analysis of growth in China in general. Section 3 describes the data and considers the question of the appropriate definition of the regions. The model estimation and simulation are reported in section 4, beginning with the simulations based on our “natural ordering” of the regions and then going on to the sensitivity analysis of the results and a proposal of an approach that ameliorates the common correlations that underlie the sensitivity. Our conclusions are presented in the final section.

2. Literature Review

Much of the empirical work on regional growth in China has been carried out in the context of the convergence question in long-run growth theory which goes back at least to the work of Kuznets (1955), Williamson (1965) and, more recently, Barro and Sala-i-Martin (1992). The work there revolved around the prediction of the standard growth model that, under certain conditions, countries’ output per capita should converge to a common level over time. While originally applied to cross-sections of countries, it has more recently been applied to regions in a given country since internally consistent data of this type are generally more easily available than cross-country data and because regions of a particular country are more likely to satisfy the underlying conditions for convergence. With the recent availability of a long run of time series on real output for the Chinese provinces (see Wu, 2004 for a recent description of these data), the empirical convergence analysis has also been extended to China. A selection of recent papers analysing Chinese regional data in this framework are by Chen and Fleisher (1996), Fleisher and Chen (1997), Kanbur and Zhang (1999), Yao and Zhang (2001a,b), Demurger (2001), Chang (2002), Lu (2002), Cai, Wang and Du (2002), Yang (2002), Demurger, Sachs, Woo, Bao, Chang and Mellinger (2002) and Demurger, Sachs, Woo, Bao and Chang (2002), Bao,

Chang, Sachs and Woo (2002). A useful summary can be found in Liu and Wei (2003) and Wu (2004).

Despite the rapidly-expanding long-run regional growth literature cited above, there has been little analysis of the short-term fluctuations in output and in particular of the interaction between regional output levels which is necessary to address the spillover issue which is at the centre of this paper and of the policy-issues identified earlier in this section. Indeed, there is little econometric work analysing spillovers for any country.

A set of papers which analyse inter-regional spillovers using US data within the framework of a vector-autoregressive (VAR) model has been produced by researchers at the Federal Reserve Bank of San Francisco: Sherwood-Call (1988), Cromwell (1992) and Carlino and DeFina (1995). Of these the last is a specific analysis of the inter-regional spillover question in a vector-autoregressive (VAR) model applied to eight US regions to assess the effects of shocks to income growth in one region on income growth in other regions. Carlino and DeFina use 60 years of annual per capita income growth data for eight US regions to estimate and simulate a VAR model, reporting tests of block exogeneity, impulse response functions (IRFs) and forecast error variance decompositions. They find significant and persistent spillover effects and argue that an understanding of these is important to the formulation of effective regional economic policy.

Other more recent papers in the same analytical vein are by Clark (1998), Rissman (1999) and Kouparitsas (2002). Kouparitsas uses a model and data similar to that used by Carlino and DeFina but a more sophisticated decomposition of income into trend and cyclical components. In contrast to the earlier findings, he concludes that regional spillovers account for a negligible part of regional income fluctuations in the US. Thus, while the use of the VAR model is well-established in US regional research, results are far from clear.

To our knowledge, only four papers have explicitly examined inter-regional spillovers for China, each of which uses a different method of analysis. The first, by Ying (2000) applies “exploratory spatial data analysis” which uses time-series data for provincial growth rates to compute (static) relationships between each province’s growth rate with those geographically near to it. Both positive and negative relationships are found with the strongest significant influence being exerted by Guangdong province which was for this reason identified as the core. Four of the five

adjacent provinces showed a significant relationship to Guangdong growth: there were positive spillovers to Hainan and Guangxi but negative ones to Hunan and Jiangxi. Thus Ying has found significant growth relationships between the provinces. However, the technique of spatial data analysis is essentially one of static growth correlations which does not permit the analysis of the strength and timing of the relationships, questions that are also vital for policy-formulation and central to the interest of this paper.

The second paper to explicitly assess the nature of regional spillovers in China is by Brun, Combes and Renard (2002). They use provincial-level time series data for real per capita growth rates for the period 1981-1998 to estimate a set of conventional provincial growth equations which are modified to include the variables representing the coastal, central and western regions. This modification is designed to capture the inter-regional spillovers and allows them to test the significance of spillovers from the coastal region to individual provinces in the other two. They do not entertain spillovers from either of the other two regions. They find significant spillovers from the coastal region to provinces in the central region but no effect on the western region. They do not, however, entertain the possibility of spillovers from central and western regions and, perhaps more importantly, they do not incorporate feedback effects but treat the regional variables as exogenous in their growth equations. They are therefore able only to test for significance and not to analyse the shape of dynamic interactions between the regions.

The third paper to analyse regional spillovers in China is by Zhang and Felmingham (2002) who analyse it as an addition to a study of the relationship between exports, FDI and growth in China at the provincial level. For their spillover work they group the provinces into three traditional regions of coast, centre and west and assess the significance of spillovers from the coast to the centre and the west and from the centre to the west. Their framework is similar to that of Brun *et al.* in that they simply add a regional spillover term to otherwise conventional growth equations. Their results are clear-cut and similar to Brun *et al.*'s in that they find spillovers from the coast to the centre but, in contrast to Brun *et al.*'s, they also find spillover to the west from both the coast and the centre. Like the previous papers, they do not include any dynamic effects, using just a contemporaneous spillover term.

The final extant paper is by Groenewold, Lee and Chen (2005) which uses annual data for three regions (conventionally defined as coastal, central and western)

for the period 1953-2003 to estimate and simulate a VAR model. In that paper it is found that there are strong spillovers from the coastal region to both other regions, from the central region to the western region but that shocks to the western region have no flow-on effect for the other two regions. They thus reach a tentative policy conclusion that developing the coastal region is likely to indirectly benefit the other two regions.

In this paper we follow the Groenewold *et al.* analysis by using a VAR model since it provides flexibility in the analysis of dynamic interactions between the regions. Moreover, it is parsimonious in its data requirements and does not require the imposition of a prior theoretical framework. As stated in the previous section, we extend their analysis in two directions. In the first place we extend the number of regions from three to six and, secondly, we subject our results to extensive sensitivity testing in view of the strong correlations between the regions.

3. Data and Definition of the Regions

The data used for regional real GDP are constructed from newly available annual series on real provincial GDP for the period 1953-2003. The sources of the data are two-fold: the early data come from Wu (2004) who obtained the 1953-1995 series from *China's GDP Data 1952-95* (State Statistical Bureau, 1997). Data for 1996-2002 come from the *Statistical Yearbook of China* (State Statistical Bureau, various years) and for 2003 from the *China Statistical Abstract* (State Statistical Bureau, 2004).

The three regions defined by Groenewold *et al.* (2005) are coastal, central and western regions. Since we compare our results to theirs, we reproduce their regional definitions here. The composition of these three regions is conventional and is as follows. Coastal: Beijing, Tianjin, Hebei, Guangdong, Shandong, Fujian, Zhejiang, Jiangsu, Shanghai, Liaoning, Guangxi; Central: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan; Western: Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.⁴

The allocation of provinces into six regions is based mainly on Liu (1985). A minor modification to his scheme is that we allocate Inner Mongolia to one region

⁴ Note that Hainan, Chongqing and Tibet are missing. Hainan is included in Guangdong and Chongqing in Sichuan. Tibet has been omitted altogether due to missing data.

whereas he allocated it to two regions. We were unable to follow his allocation because we do not have sub-provincial real output data. Although this six-region scheme was first advocated about 20 years ago, the division continues to be valuable, reflecting the geography proximity and geography and economic homogeneity and coincides with the regional policy of central government to some extent. The details of the allocation are as follows.

The South East (SE) region consists of Guangdong (including Hainan), Fujian and Guangxi provinces. The three provinces neighbour Hong Kong, Macao and Taiwan and so have the advantage of accessing the international market and foreign direct investment; most overseas Chinese, many of whom are sources of FDI in China, come from this region. It is also the region which first opened its doors to the world; for example, the four special economic zones were set up in Guangdong and Fujian early in 1980. Though Guangxi is relatively poorer and has been defined as a western province in the Great Western Experiment advocated by the central government in 1999, it is still allocated to the coastal region by most researchers since it has a higher growth rate and receives more FDI than most western provinces (Yao and Zhang, 2001a).

The Changjiang River (CR) region consists of Shanghai and Jiangsu, Zhejiang, Hubei, Hunan, Jiangxi and Anhui provinces. These provinces are located along the Changjiang River.⁵ Most private corporations and so much private capital are located in Zhejiang and Jiangsu. Shanghai is the financial, commercial and “high-tech” centre of China and also the richest province. The central provinces of Hubei, Hunan, Jiangxi and Anhui are relatively poorer than Shanghai, Zhejiang and Jiangsu,⁶ but they have abundant nature resources; for example, their land is fertile and the climate is mild and so agriculture is well developed and productive, which helps them to complement their coastal counterparts in this region. It is expected by the central government that this region will be developed into the biggest economic zone of China.

⁵ Strictly speaking, this is the lower-middle Changjiang River region since other provinces such as Chongqing and Sichuan are also located along the upper reaches of the Changjiang River. However, for brevity, we use the term Changjiang River region rather than the more cumbersome Middle-Lower Changjiang River region.

⁶ Thus Shanghai in 2003 had a per capita GDP of 46718 yuan compared to that of Guizhou, for example, which managed only 3601. Other provinces in the region fared as follows: Zhejiang, Jiangsu, Hubei, Hunan, Jiangxi and Anhui had per capita GDP of 19730, 16796, 9001, 7546, 6677, 6889 respectively. *China Statistical Abstract, 2004*

The Yellow River (YR) region consists of Inner Mongolia, Henan, Shanxi, Beijing, Tianjin, Shandong and Hebei.⁷ These provinces closely cluster around the core Beijing and Tianjin, two of the four city-provinces of China. Energy resources, such as coal in Shanxi and Inner Mongolia, and oil in Shandong, are abundant and so the mining and processing industries are well developed in this region. In terms of geography, most of the region is located in the HuaBei Plain, the soil and climate of which make it the agricultural heartland of China, since there are few mountains in this region. One potentially serious problem in this region is the lack of water though currently a vast scheme to deliver water from the Changjiang River to the north is being constructed in order to meet the water demand of this regions (especially for the national capital Beijing).

The North East (NE) region consists of Heilongjiang, Jilin and Liaoning provinces. Historically these three provinces are closely connected. As pointed out earlier, these provinces emerged in 1949 as relatively highly industrialised, more closely connected and somewhat separate from the rest of the country. After the birth of the People's Republic of China much was invested in this region during the period of the first two Five-Year Plans in order to build on this base and develop a system of heavy industry.⁸ As a result, a complete industrial structure and production organization were set up during this early period so that by 1978 this region was one of the richest in China. Now, however, the region faces the dual problems of resource depletion and obsolete industry in urgent need of upgrading. Recently the central government advocated a strategy to help revitalise the old industry base.

The South West (SW) region includes Yunnan, Guizhou, Sichuan (including Chongqing) provinces. These three provinces are located in the tableland (with an average elevation of 1,428 meters and average slope of 5.2 degrees) and so the land is poor and transport is inconvenient and therefore costly. Though a few cities such as Chengdu (the capital of Sichuan) and Chongqing have developed quickly recently, most of the region is still very poor, partly because of its geography but also because it is over populated (the population of Sichuan and Chongqing is more than 100 million). One advantage of this region (especially for Yunan) is its ability to develop border-trading since they neighbour some southern and eastern Asian countries.

⁷ The same comment applies to the Yellow River region as for the Changjiang River region, i.e., while this is called the Yellow River region, there are other provinces along the upper Yellow River which are not included in this region.

⁸ Thus, for example, the first auto factory in China was set up in Changchun, the capital of Jilin.

The North West (NW) region consists of Xinjiang, Gansu, Qinghai, Ningxia and Shaanxi provinces. In this region there are plentiful natural resources such as coal, natural gas and oil, but the energy industry tends to form an enclave and has not induced development of the region as a whole. The arid natural environment (it is marked by deserts on its northern and western borders) and lack of water make this region difficult for agriculture. Most of the people in this region are still very poor. While there are grasslands suitable for grazing, these are in grave danger of desertification due to overgrazing and the fragile nature of the environment. All provinces in this region face the dilemma of developing the economy while also enhancing the natural environment.⁹

Maps showing the three- and six-region divisions of China are shown in Figures 1 and 2.

[Figures 1 and 2 near here]

4. Results

As indicated earlier, the framework we use for the analysis of inter-regional spillovers is a vector autoregressive (VAR) model. To clarify the nature of the dynamic analysis it is useful to start from a general linear p th-order dynamic model in the n -vector of variables $\underline{x}_t$:

$$B(0)\underline{x}_t = \underline{b}_0 + B(L)\underline{x}_{t-1} + \underline{\varepsilon}_t \quad (1)$$

where $B(0)$ is an $(n \times n)$ matrix of coefficients capturing the contemporaneous effects between the x s and $B(L)$ is a p th-order matrix polynomial in the lag operator, L :

$$B(L) \equiv B(1) + B(2)L + B(3)L^2 + \dots + B(p)L^{p-1} \quad (2)$$

⁹ It has been said that the reason why the central government advocated the Great Western Experiment is that the sand from the NW provinces has been blown to Beijing causing several severe sandstorms in 1998.

and $L^j \underline{x}_t \equiv \underline{x}_{t-j}$. The ε s are the structural error terms which are mutually independent. Our dynamic analysis consists of shocking one of these errors at a time and tracing the effects on all the x s over time, the results being captured in the impulse-response functions (IRFs).

The model in (1) cannot be estimated as it stands since it is not identified. Instead the (reduced-form) VAR is usually estimated. It is derived from (1) as:

$$\underline{x}_t = \underline{a}_0 + A(L)\underline{x}_{t-1} + \underline{e}_t \quad (3)$$

where $\underline{a}_0 \equiv B(0)^{-1} \underline{b}_0$, $A(L) \equiv B(0)^{-1} B(L)$ and $\underline{e}_t \equiv B(0)^{-1} \underline{\varepsilon}_t$. This system of equations can be validly estimated using OLS and, at best, we can obtain estimates of the reduced form errors (rather than the structural errors) in the form of VAR residuals.

The moving-average (MA) form of the model is used for generating the IRFs and is derived from the (reduced-form) VAR model, equation (3), as:

$$\underline{x}_t = \underline{c}_0 + C(L)\underline{e}_t \quad (4)$$

where $C(L) \equiv (I - A(L)L)^{-1}$, $\underline{c}_0 \equiv C(L)\underline{a}_0$ and I is the identity matrix of appropriate order.

Since we wish to simulate the effects of shocks to the structural errors, we need to identify the ε s. There are various ways of accomplishing this. The standard approach is to use a Choleski decomposition of the contemporaneous covariance matrix of the VAR errors, Σ :

$$\Sigma = PP'$$

where P is a lower triangular n -matrix. The structural errors are then written as

$$\underline{\varepsilon}_t = P^{-1} \underline{e}_t \quad (5)$$

which are contemporaneously uncorrelated and have a unit variance, given the properties of the P matrix. The effect of a shock to the j th error on the i th x variable after an elapse of τ periods is given by the value of the relevant IRF at τ :

$$IRF_{ij\tau} = \underline{i}_i' C(\tau) P \underline{i}_j \quad (6)$$

where $\underline{i}_k$ is an n -vector of zeros except for a 1 in the k th position and $C(\tau)$ is the τ th matrix in the matrix polynomial $C(L)$.

A potentially serious drawback of this approach is that the P matrix is not unique and therefore the IRFs are not unique. In particular, in the standard applications of the Choleski approach the IRFs depend on the order in which the variables are listed in the model, an ordering which often has an arbitrary element. This weakness is mitigated where a particular ordering can be justified *a priori* or where the contemporaneous correlation between the VAR errors is weak.

Before deriving the IRFs, we need to attend to two preliminary matters. First, in empirical analysis based on time-series data it is customary to assess the stationarity of the data and to difference the data if non-stationary (unless the variables are cointegrated). Thus, e.g., Groenewold *et al.* (2005) tested the (logs of) regional real output for a unit root and found that all three series were stationary about trend if breaks in level and trend at 1966 and 1978 were allowed for. We also tested the significance of trend and breaks at these dates in our six-region data and found trend to be significant but the break dummy variables were never significant and were therefore omitted. We did not test specifically for stationarity since it is not required if we do not wish to undertake hypothesis tests but focus on dynamic analysis.¹⁰ Besides, the IRFs generally converged at about the same rate whether the dummy variables are included or not; moreover, simulation results for the short to medium term were not substantially affected by the presence of the break dummy variables. We therefore estimated the model in log levels and included a trend in each equation.

The second preliminary matter is that of lag length. Groenewold *et al.* found that two lags was sufficient to eliminate all autocorrelation in the equation residuals. We therefore started with two lags and tests of autocorrelation indicated that this was

¹⁰ See Estima (2004, p.331) for a brief discussion of the issue of differencing; they suggest not to difference even if the data are non-stationary because of the loss of information balanced by no substantial efficiency gain.

sufficient to capture the systematic variation in the data. The IRFs which follow were therefore generated by a VAR(2) model in the six (log) real output variables (and trend and intercept).

We begin by analysing the VAR with the variables in a “natural order”. Groenewold *et al.* (2005) in their three-region model argued for a natural ordering of the regions: coastal, central and western. While this seems obvious and defensible in the three-region case, a natural ordering for the six regions used in the present paper is not quite so clear. We chose: SE, CR, YR, NE, SW, NW since this most closely approximates the economic importance of the regions in policy discussion as well as the presumed direction of spillovers in such discussion.¹¹ However, since this is not likely to be uncontroversial and the presumption in policy discussion may well be wrong, we experiment extensively with alternative forms of the model to assess the sensitivity of the results.

The IRFs for our natural ordering are presented in Figures 3 to 8.

[Figures 3 to 8 near here]

Before attempting a detailed discussion of the implications of these figures for the nature of inter-regional spillovers, we should investigate the sensitivity of these to the ordering that underlies them. Clearly many alternative orderings of the variables are possible. To illustrate the effect of a change in order we report IRFs for just one alternative, viz., the reverse of the natural one. They are reported in Figures 9 to 14.

[Figures 9 to 14 near here]

Even a cursory comparison of the corresponding IRFs shows that there is considerable sensitivity to the order in which the variables are included in the model. The most dramatic difference occurs when the shocked variable in one of the orderings is in the first position. Thus a comparison of the effects of a shock to the SE region in Figure 3 to that in Figure 9 shows a considerable difference – so great that very different conclusions regarding spillover would be drawn if they were considered equally

¹¹ The relationship between the order of the variables and spillover follows from the implication of the Choleski orthogonalisation that a shock to the first-listed variable may contemporaneously affect all others, a shock to the second may affect all others except the first and so on. This follows from the triangularity of the matrix P and will be obvious in the first period values of the IRFs.

plausible. A comparison of the effects of a shock to the NW region in Figures 8 and 14 shows a similar difference. However, the comparison of IRFs when the variable is not in the first position in either of the orderings shows much less difference. Further experimentation (the results of which are not reported here) shows this to be a general feature of the results – it matters a great deal whether the shocked variable appears first in the list or later but it matters little how much later in the list. It is well known (see, e.g., Enders, 1995) that in practice the severity of this sensitivity depends on the contemporaneous correlation of the residuals of the VAR. Indeed, under the Choleski orthogonalisation the first-listed variable is assigned all the common correlation of the errors. Thus the results suggest strong common correlations among the equation errors which we examine by looking at the correlation matrix for the residuals; they are reported in Table 1.

[Table 1 near here]

It is clear from Table 1 that there is generally a high correlation between the equation residuals; this confirms our conjecture for the reason behind the sensitivity of the IRFs to variable ordering. All correlations are positive and substantial – the lowest is 0.5454 between SW and NE regions (not surprising in light of their geographic separation) and the highest is 0.9534 between NE and YR with the average being approximately 75%.

One way of overcoming the sensitivity of the IRFs to the variable order (the “ordering problem”) is to simulate the model under the assumption that the errors can be shocked independently, despite the empirical evidence that they generally move closely together. This is the approach of Carlino and DeFina (1995) in their application of the VAR model to the issue of inter-regional spillovers in the US. They use a particularly simple version of the Bernanke-Sims identification procedure which allows them to shock each of the VAR errors in turn while holding the others fixed on the assumption that the within-period spillovers are small enough to be ignored.¹² While this violates the observed empirical regularities over the sample period, it is nevertheless appropriate if the researcher is of the view that policy can, say, boost output in a particular region without at the same time directly affecting output in any

¹² See Bernanke (1986) and Sims (1986).

of the others and that there are no significant within-period spillovers to other regions.

The results of such an exercise for our six-region model is pictured in Figures 15 to 20.

[Figures 15 to 20 about here]

Compared to the IRFs based on the Choleski orthogonalisation and the variables in their natural order shown in Figures 3 to 8, the greatest difference is again the IRF for the SE region. The simulation underlying Figure 3 allows all other regions to react contemporaneously to the SE shock while in Figure 15 none is allowed to do so. The differences become smaller the further down the order we proceed – when we reach NW (Figures 8 and 20) the two IRFs are identical since in both cases no other region is allowed a contemporaneous reaction. The conclusions reached regarding the strength and direction of spillovers are therefore quite different to those based on the original simulations and importantly affected by the particular way in which the model is shocked.

The Carlino and DaFina approach has solved the ordering problem since the results in Figures 15 to 20 are now independent of the variable ordering but a weakness of this approach is that one may doubt the possibility of stimulating a region in such a way that adjoining regions are not affected. This is particularly so because we use annual data so that even if the regions can be stimulated independently there is quite a possibility of within-period spillovers. Moreover, it is likely to be a more serious problem the smaller the regions and therefore more of a problem in our six-region model than it would in a three-region one. We therefore proceed to an exploration of alternative solutions to the ordering problem.

We have argued that the ordering problem arises from the high degree of correlation between the equation errors. It is likely that this results from a large common component in the shocks that have historically hit the regions. It is possible that this is an artificial feature of the data resulting from the method of constructing GDP data in China. There are many anecdotal accounts of this process, most of them uncomplimentary to the Chinese National Bureau of Statistics; see Xu (2004) for a recent official account and Holz (2004) for a more critical view. Any flaws in the construction of aggregate GDP data are likely to be at least more severe at the provincial level. However, whatever the truth of such problems with the data may be,

we proceed as most empirical analysis of national accounting data does (and that not just for China) on the assumption that the data are what they are claimed to be and leave the intriguing problem of data quality to another time. We therefore treat the strong common correlations as functions of the way in which the Chinese economy operates and explore ways of mitigating the effects of this on the VAR analysis.

One way forward is to attempt to purge the regional outputs of this common component. If the common component is a linear trend then a straightforward measure to remove the common correlation is to detrend the data by regressing it against a trend (and constant). For this case we report the residual correlation matrix in Table 2.

[Table 2 near here]

If we compare the results to those in Table 1, we see that the correlations have changed little – some have increased slightly and others have fallen slightly; the average correlation is almost identical for the two models. On this basis it is reasonable to suspect that the ordering problem has not been solved and an inspection of a range of IRFs (not reported) confirms our suspicion. We therefore continue our exploration.

The fourth variation on the original model is based on the view that the high correlation amongst the equation errors is caused by a large part of the shock hitting any particular region being national shocks which affect all the regions to a greater or lesser degree. If we capture these by fluctuations in the national real output level we can purge the regional outputs by “detrending” them using national output rather than a linear trend. When such “nationally-detrended” data are used in a VAR(2) model, the error correlations are those reported in Table 3.

[Table 3 near here]

The correlations are considerably reduced compared to the linearly detrended results – several of the correlations are now negative but overall the magnitude of the correlations is much smaller. We would expect then that the IRFs would be less sensitive to the ordering of the variables in the VAR model and this is indeed the case. We assessed the sensitivity of ordering by examining the IRFs for a large number of

possible variable orderings. As we found with an earlier version of the model, most of the variation in the IRFs occurs when the shocked variable is shifted between first and second positions – further shifts to positions lower than the second have little additional effect. But in this case even the change effected by shifting the shocked variable from first to second in the list was relatively minor and we therefore focus on the IRFs based on the Choleski orthogonalisation where in each case the shocked variable is in the first position. These are reported in Figures 21 to 26.

[Figures 21 to 26 about here]

Given the relative insensitivity of these simulations to variable ordering, we take these as the preferred IRFs and proceed to a more detailed description of the simulations pictured in the figures.

A shock to the SE region has its main effect on the region itself with trivial effects on the other regions except for the NE region which is negatively affected by the shock to SE. All effects last only a relatively short time. Recall that the SE region consists of Guangdong, Fujian and Guangxi provinces, at least the first of which has long been considered one of the driving forces of Chinese economic growth. It is surprising, therefore, that its region seems to have only trivial spillover effects.

The effects of a shock to the CR region are only short-run with positive effects only on the region itself and on the SE region. There are trivial effects only on YR and SW regions and actually negative effects on NE and NW regions. These results are not surprising if they are considered in terms of geographic proximity. The CR region almost encircles the SE region while having only limited connection with the YR and SW regions and almost no contiguity with the two northern regions, NW and NE.

A shock to the YR region has a more widespread positive effect on the regions with all regions' output being higher in the short to medium run and the effects also being generally longer-lasting than was the case for the SE shock. Only the NW region seems to be relatively unaffected. The YR region consists of Beijing, Tianjin, Inner Mongolia, Henan, Shanxi, Shandong, Hebei with the economic and political core being the first two of these. They have been central in Chinese economic growth policy and it is not surprising to find that stimulating these provinces has beneficial side-effects on other regions.

The results for a shock to the NE region show that there are substantial short-run effects only on the region itself; there are trivial effects on all other regions except for the SE which actually reacts negatively to a positive shock to NE. Moreover, the effects of the shock are only short-lived. Thus it appears that the NE region is relatively economically isolated from the remainder of the country. It is interesting that the three provinces which constitute this region (Heilongjiang, Jilin and Liaoning) were the recipients of considerable development resources early in the history of the PRC but that their productive capacity has since become relatively obsolete and resources depleted. The simulation results here show that they have become relatively isolated from the rest of China in terms of economic inter-connections; it appears that stimulation of the economies of these provinces would have only weak spillovers for the country as a whole.

The same is true of the SW region which consists of Yunnan, Guizhou, and Sichuan provinces – the effects of a shock to this region are limited to the region itself although the effects are longer-lived. Given the geographic isolation of these provinces, the economic effects are not a surprise.

Finally, the NW region appears to have more widespread effects on other regions although the magnitude of the effects is relatively small. In particular, a positive shock to the NW provinces also has a substantial beneficial effect on the SW region and, to a lesser extent, on the NE region. There are interesting repercussions for the SE region – while this region is not immediately affected, there are substantial effects starting after about four years which persist for almost a further 10 years. Given that these two regions are at opposite ends of the country, this clearly cannot be explained in terms of geographic proximity.

In conclusion, we can infer from our model simulations that only two of the six regions have very general spillover effects – the Yellow-River provinces and the North-West region both affect several other regions although the magnitude of the effects is modest. The Changjiang-River region has a strong spillover effect but only on one other region, viz. the South-East region. Predictably perhaps, shocks to the North East and South West regions have little effect on the other regions. Surprisingly, though, the South-East region itself (which includes Guangdong province) has no effective spillovers.

These implications of our results provide interesting contrasts to some major regional policy initiatives as well as some of the findings of earlier literature. On the policy front, the relative isolation of the South East runs contrary to strong policy expectations of benefits to be derived for the country as a whole from stimulation of the South East region. It was the first to be opened to the world economy and yet appears to have had little beneficial effects on the surrounding regions. Moreover the Changjiang region centred on Shanghai also received significant policy stimulus – the Pudong Development Zone was set up in 1989 with strong expectations of benefits extending beyond the region itself, yet the spillovers seem to be very limited according to our results. Similarly, the 2002 policy, the Resurgence of North-Eastern Old Industry Base centred on the North East region seems destined to affect only that region. In contrast, the Great Western Experiment may have unexpected spillovers, at least to the extent that it is effected in the North West region.

It is also interesting to consider our results in the light of earlier literature reviewed in Section 2. Ying (2000) found Guangdong province to be highly connected to its neighbouring provinces. This is consistent with the findings of Brun *et al.* (2002), Zhang and Felmingham (2002) and of Groenewold *et al.* (2005) who, all using three regions, find spillovers from the coastal to the central province and, in the latter two cases, also to the western region.

Our findings contrast strongly with Ying's since our SE region was found to have no strong spillovers at all, although in qualification it must be pointed out that Ying used only correlation analysis and our regions are less disaggregated than his.

Our analysis is closest to that in Groenewold *et al.* in that both use dynamic simulations in a VAR model. They found spillovers from the coastal region to the rest of the country, from the central region to the western region but not to the coast and that the western region had no effects on either of the other two. There are some similarities to our results. For example, we find the South Western region to have no spillover effects (like the western region) and the Changjiang River and Yellow River regions to have spillover effects somewhat similar to those of the coastal and central regions. However, there are also contrasts – the South East and North East regions (both containing important components of the coastal region) have no significant spillovers but the Northwest region does have general spillovers.

If one were tempted to draw policy conclusions, they would be that the stimulation of the Yellow River region would have the most beneficial widespread

effects. This is more nuanced but not altogether consistent with the simpler implications arising from earlier simpler models: stimulate the coast and the rest of the country will follow. Our analysis suggests this is simplistic in that not all parts of the coastal region are equally worth boosting. But these can be only tentative policy implications. The contrasts and similarities highlighted above underscore the importance of experimenting with different regional definitions since it appears that different parts of a region may have quite different effects. It may also be the case that the Groenewold *et al.* results reflect to a large extent their *a priori* ordering assumption which underscores the virtue of sensitivity analysis.

4. Conclusions

This paper has examined the question of inter-regional spillovers in China. We argued that this is a central question in Chinese economic policy, given the marked regional disparities that exist and the concern of policy makers to ameliorate them.

We analysed this question within the framework of a six-region VAR model which we subjected to extensive sensitivity analysis. We found the results to be importantly dependent on model specification, in particular, on the order in which the variables entered the model. After extensive experimentation we were able to specify a model with tolerable robustness by using data which had been purged of national output fluctuations. We found some expected but also some unexpected results. Not surprisingly, the Yellow River and Changjiang River regions had spillover effects although they were more extensive for the former; the South Western region had no significant spillovers effects on the rest of the country, consistently with other research results. However, in contrast both to other research and to our expectations based partly on major regional policy initiative, shocks to the South East and North East regions affect mainly the regions itself with little spillover to the other regions while the South West region have general spillover effects. We drew some tentative policy implications which differed to the common advice of “boost the coastal provinces and the rest of the country will follow” but our main conclusion is that there is still much to be learned about inter-regional spillovers and that there is room for both further experimentation with other regional aggregations and for testing of results to model specification. This will become increasingly attractive as more data become available.

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Table 1: Residual correlations; log-linear model with trend

	SE	CR	YR	NE	SW	NW
SE	1.0000	0.7190	0.7151	0.6599	0.6827	0.7654
CR		1.0000	0.8980	0.8965	0.6591	0.8158
YR			1.0000	0.9534	0.6935	0.8819
NE				1.0000	0.5454	0.8595
SW					1.0000	0.7642
NW						1.0000

Table 2: Residual correlations; log-linear model with detrended data

	SE	CR	YR	NE	SW	NW
SE	1.0000	0.7523	0.7403	0.6272	0.7038	0.7475
CR		1.0000	0.9059	0.8638	0.6829	0.8057
YR			1.0000	0.9294	0.7132	0.8751
NE				1.0000	0.5409	0.8581
SW					1.0000	0.7655
NW						1.0000

Table 3: Residual correlations; “nationally-detrended data”

	SE	CR	YR	NE	SW	NW
SE	1.0000	0.4274	0.0284	-0.5035	0.0791	-0.1020
CR		1.0000	0.2488	-0.2758	-0.1771	-0.5564
YR			1.0000	0.4277	0.0439	-0.0943
NE				1.0000	-0.2205	0.3278
SW					1.0000	0.2852
NW						1.0000

Figure 1: The three regions

Figure 2: The six regions

Figure 3: Shock to SE; log-linear model, Choleski orthogonalisation, natural order

Figure 4: Shock to CR; log-linear model, Choleski orthogonalisation, natural order

Figure 5: Shock to YR; log-linear model, Choleski orthogonalisation, natural order

Figure 6: Shock to NE; log-linear model, Choleski orthogonalisation, natural order

Figure 7: Shock to SW; log-linear model, Choleski orthogonalisation, natural order

Figure 8: Shock to NW; log-linear model, Choleski orthogonalisation, natural order

Figure 9: Shock to SE; log-linear model, Choleski orthogonalisation, reverse order

Figure 10: Shock to CR; log-linear model, Choleski orthogonalisation, reverse order

Figure 11: Shock to YR; log-linear model, Choleski orthogonalisation, reverse order

Figure 12: Shock to NE; log-linear model, Choleski orthogonalisation, reverse order

Figure 13: Shock to SW; log-linear model, Choleski orthogonalisation, reverse order

Figure 14: Shock to NW; log-linear model, Choleski orthogonalisation, reverse order

Figure 15: Shock to SE; log-linear model, independent shocks

Figure 16: Shock to CR; log-linear model, independent shocks

Figure 17: Shock to YR; log-linear model, independent shocks

Figure 18: Shock to NE; log-linear model, independent shocks

Figure 19: Shock to SW; log-linear model, independent shocks

Figure 20: Shock to NW; log-linear model, independent shocks

Figure 21: Shock to SE: “nationally-detrended” data

Figure 22: Shock to CR: “nationally-detrended” data

Figure 23: Shock to YR: “nationally-detrended” data

Figure 24: Shock to NE: “nationally-detrended” data

Figure 25: Shock to SW: “nationally-detrended” data

Figure 26: Shock to NW: “nationally-detrended” data