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The Unbalanced Growth Hypothesis and the Role of the State: the Case of China's State-owned Enterprises

Albert Hirschman's unbalanced growth hypothesis suggests that a developing economy can promote economic growth by initially investing in industries with high backward and forward linkages. In the case of Chinese economic policy today, one application would be the continued presence of the state in high-linkage sectors and the strategic withdrawal of the state from low-linkage sectors. The evidence shows that while the degree of linkage plays an important role in generating economic growth in China, province-specific withdrawal strategies for the state sector have no effect on economic growth.

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1. Introduction

European reconstruction after World War II and Latin America's development efforts spurred economists to explore options for promoting economic development. Authors discussed the need for a big push (Rosenstein-Rodan, 1943, 1984), growth with an unlimited supply of labor (Lewis, 1954), stages of economic growth (Rostow, 1956), and balanced vs. unbalanced growth (Nurske, 1953, and Hirschman, 1958). Hirschman questions if a big push can overcome a low-level equilibrium trap of development and suggests instead an unbalanced growth strategy. He argues that by concentrating investment in key industries, governments can create supply bottlenecks for inputs in these industries. The supply bottlenecks create profit opportunities in upstream industries and thereby induce private investment ("backward linkages"). Similarly, domestic production of a new product is likely to create profit opportunities in downstream industries and thereby induce private investment in downstream industries ("forward linkages").

The unbalanced growth hypothesis was put to the test by Yotopoulos and Nugent (1973) in a cross-country study. The authors, through quantitative analysis relating linkage coefficients to economic growth, reject the unbalanced growth hypothesis but accept what they call a "balanced-growth" version of the linkage hypothesis in that conformance to a particular imbalance pattern defined by sectoral linkage coefficients leads to high growth. Their findings triggered extensive comments, with a rejoinder by Yotopoulos and Nugent (1976).[1]

More recently, the concept of unbalanced growth has resurfaced, though not always explicitly, in literature ranging from a U-shaped pattern of sectoral diversification during the development process (Imbs and Wacziarg, 2003) to industrial policy discussions. Cohen (2007) distinguishes between vertical (sector-specific) and horizontal (framework) industrial policy; the unbalanced growth hypothesis fits squarely into the vertical industrial policy category. Hausmann, Rodrik, and Sabel (2008) distinguish between industrial policy "in the small" (putting mechanisms into place to identify and remove roadblocks facing existing economic activities) and industrial policy "in the large" (strategic bets on industries one would want to see develop); the linkage element of the unbalanced growth hypothesis would provide a criterion for making strategic bets.[2]

While the focus of the industrial policy discussion tends to be on optimizing growth, Hirschman is more concerned with *entering* a growth trajectory at an early stage of development. Rodrik (2010, p. 93) writes that "good industrial policy attempts to enhance the relative profitability of non-traditional products that face large information externalities or coordination failures, or which suffer particularly strongly from the poor institutional environment." Hirschman might have found that *all products* associated with industrialization face large information externalities. Where Rodrik (2006) suggests that "the government is only focused on providing complementary inputs to the market" (p. 25), Hirschman sees a larger role for the government that includes directly productive activities.

The case of China allows us to revisit the unbalanced growth hypothesis in a Hirschmanian environment of a country at an early stage of economic development—with per capita GDP one-fifth that of Korea and less than one-tenth that of the U.S. and other Western economies—and endowed with far from perfect institutions. Furthermore, the available data for China allow the use of a new version of linkage indicators that more accurately reflects Hirschman's intentions than the indicators used in the linkage literature. However, the case of China also differs from that of the typical developing economy which Hirschman may have had in mind in that China, at the outset of economic reforms in 1978, had in place a balanced industrial base and the government was already strongly involved in the economy. This creates the opportunity for a unique application of the unbalanced growth hypothesis.

In the pre-reform Chinese economy, planners aimed for balanced growth. As explained in a Chinese university textbook on planning by Li (1983/88, p. 17), the planned economy is superior to the market economy because it leads to "balanced and continuously rapid economic development of social production" and the "rational use" of resources, "thereby avoiding the enormous waste inherent in the anarchic production under capitalism." Similary, Zhong (1988), in another university textbook on planning, elaborates on "comprehensive balancing" and “proportional development.” Neither textbook shows any awareness of linkage effects (or input-output analysis). Naughton (2007, Chapter 3) describes the period 1949-1978 as one of “big push industrialization,” implicitly ruling out any application of the concept of unbalanced growth.

In the reform period, the question then is not so much one of which sector to develop first in the face of severe resource constraints, as one of how to allocate *state* resources when economy-wide planning is in regress. Chinese policy makers in the reform period face choices as to which industries to continue to invest in, and from which industries to withdraw. At a time when private entrepreneurship is not yet well developed and the institutions to support large-scale private investment are not yet in place, government policies on the sectoral distribution of state involvement in the economy could be crucial to economy-wide growth. If linkage effects matter for economic growth, then Hirschman’s theory of unbalanced growth applied to a transition economy such as China implies that the government can maximize economy-wide growth if it continues to play an important role in sectors with high linkage effects on profit opportunities in other sectors, and withdraws from sectors with low linkage effects.

China is an ideal testing ground because it offers 8 regional and 31 provincial observations, all subject to a similar institutional and cultural environment. The cohesion within a nation state avoids the issues of data comparability that beset cross-country studies, whether that is differences in data compilation methods or in economic institutions, all of which are difficult to control for. China’s regions are of the size of the U.S. (or Europe, or Japan), and China’s provinces are of the size of individual European countries, i.e., match countries in cross-country studies.

At the beginning of the reform period in 1978, each province enjoyed relative self-sufficiency with state involvement across all sectors. As reforms progressed, provinces increasingly chose their own paths of development. Fiscal decentralization that allowed localities to retain the returns to economic growth combined with a cadre evaluation system that emphasized local growth created incentives for localities to strive for maximum growth. The cellular structure of the Chinese economy (with only few resources traded across provincial boundaries, typically by central agents) coalesced into national markets that allowed the pursuit of province-specific growth strategies and increasing local specialization (Holz, 2009).

The question of to what extent the Chinese local state favors the development of high-linkage sectors could cover all aspects of state interventionism, from a variety of industrial policies to sectoral regulatory frameworks. But policies and regulations change frequently and are rarely clear-cut (as well as near-impossible to quantify).[3] Furthermore, WTO membership, since 2001, comes with a prohibition for many types of explicit industrial policies.

This paper focuses on one, perhaps the key mechanism through which the state continuously engages in the economy, namely state-owned enterprises (SOEs). In the reform period, the market share of SOEs declined—through privatization, ownership restructuring, and the growth of non-SOEs—and this decline differs from sector to sector and from province to province.[4] The question is if the local state uses SOEs strategically to promote economic growth via linkage effects. This does not rule out other channels for harnessing the growth benefits of linkage effects, but this paper focuses on that aspect of state policy which can be quantified.

The performance of China's SOEs is often questioned. Thus, Lardy (1998, p. 22) concludes that "reforms to date have failed in large portions of the state-owned sector and that their ultimate success will depend on the willingness of the Chinese Communist Party to embrace privatization." More recently, Yusuf et al. (2006) in a World Bank study argue that "the desirable next steps for China's long-running SOE reform … would be the full privatization of industrial enterprises" (p. 42). Jefferson and Su (2006) confirm that privatization of SOEs tends to lead to better performance in the privatized SOEs.[5]

But judging SOEs by their financial performance ignores the potentially significant positive externalities of SOEs, *one of which* is the linkage effect. Other positive externalities of SOEs have been noted before. Thus, Lin et al. (1998, 2003) point to the policy-determined burdens (distorted output prices, high capital intensity, and social burdens) that place SOEs at a disadvantage in comparison to non-state enterprises. Holz (2002, 2003) in quantitative assessments finds that if circulation taxes and capital intensity are controlled for, industrial SOE profitability exceeds that of enterprises in other ownership forms. Brandt and Zhu (2000, 2001) argue for negative externalities in that the government's commitment to SOEs leads to cycles of growth and inflation. Brandt and Zhu (2010) show a (negative) impact of China's capital market distortions (in favor of SOEs) on productivity growth and thereby economic growth.

The potential linkage effect of SOEs has so far escaped attention. Can strategic sectoral retention of state ownership in high-linkage sectors have played a significant role in China's rapid economic growth? This involves two analytical elements: to what extent do linkage effects impact on economic growth, and to what extent does the Chinese government consider linkage effects in decisions on the distribution of state ownership across sectors?

The linkage effect on growth is elaborated in the following section. The linkage indicators and data are reported in the third section. The findings are presented and discussed in the fourth section. The implications are explored in a final, concluding section.

2. The linkage effect on growth

2.1 Hirschman's argument

According to Rosenstein-Rodan (1943, 1984), less developed countries are caught in a low-level equilibrium trap marked by (i) the presence of significant economies of scale which remain unexploited due to the lack of large-scale investment, (ii) a lack of social overhead capital because private enterprises cannot internalize the positive externalities of social overhead capital, (iii) severe under-investment in other areas of large positive externalities, such as in education and on-the-job training, and (iv) disguised unemployment. Government investment is necessary to provide a "big push" of initial industrialization. Once the economy has taken off, private investment will crowd in and maintain the growth momentum.

Hirschman (1958), in contrast, questions if a big push can overcome a low-level equilibrium trap of development because "its application requires huge amounts of precisely those abilities which we have identified as likely to be in very limited supply in underdeveloped countries [entrepreneurial and managerial ability]" (p. 53). He also questions the ability of government to finance simultaneous industrialization across all sectors and further cautions that investment in "social overhead capital" is in danger of being "overadvertised" (p. 86). "A moderate shortage of SOC [social overhead capital] is not likely to do too much damage to a really dynamic developing area" (p. 95), and "in a situation where SOC is not plentiful it may be more efficient to protect, subsidize, provide special finance for, or to undertake directly investment in DPA [directly productive activities] than to stimulate DPA indirectly through investment in SOC" (p. 89).

He suggests the creation of "inducement mechanisms" to help overcome the various obstacles to development (pp. 24-8). Government investment in key industries creates supply bottlenecks for inputs in these industries, and thereby profit opportunities for private investment in upstream industries. At the same time, new production of a certain product "is likely to result in efforts on the part of the producers to propagate its further uses and in their financial participation in such ventures" (p. 100). Thus, well-targeted (unbalanced) government investment can induce the development of a broad economic structure.

Hirschman (pp. 98ff.) distinguishes between the *importance* and the *strength* of the linkage effect, where importance could be captured by the net output of new industries that might be called forth, while strength would be reflected in the probability that these new industries will actually be created. The analysis of linkage coefficients cannot distinguish between importance and strength; linkage coefficients reflect the current outcome observed in the economy.

Hirschman offers two operational definitions of linkage. He first defines forward linkage of a particular industry as the proportion of total output of this industry that does not go to final demand but to other industries, and backward linkage, similarly, as the proportion of this industry's total output (input) that represents purchases from other industries. Second, a "more refined measure of backward linkage can be obtained by considering the inverse of the input-output matrix" (p. 108); he offers no counterpart for forward linkage.

2.2 Testing the unbalanced growth hypothesis

Yotopoulos and Nugent (1973) explore the applicability of Hirschman's linkage hypothesis through quantitative analysis. They consolidate the input-output tables of six developed countries and five less developed countries into one input-output table for developing countries and one for less developed countries, each with two degrees of aggregation, into six and 18 sectors. They then calculate the backward (or, in their language, "total") linkage coefficients, i.e., the direct and indirect effects of a one-unit increase in final demand for the products of a particular sector on the output of all sectors. At both levels of aggregation, with six or 18 sectors, the linkage coefficients of the two groups of countries are different in some sectors but not all; in sectors in which they are not significantly different at a 0.5 probability level, the average coefficient of all countries is used in the subsequent analysis, otherwise the group-specific coefficient. The sectoral linkage coefficients of the developed countries tend to be higher.

To examine the relationship between linkage and growth, Yotopoulos and Nugent first calculate, for each of 36 countries with 18 sectors, or 39 countries with 6 sectors, what they term the "Hirschman-compliance index," namely the correlation coefficient between the sectoral linkage coefficients and the sectoral growth rates of 1950-60. In a second step, the 36/39 Hirschman-compliance indices are correlated with the economy-wide growth rates. For a variety of scenarios (6 sectors or 13 manufacturing sectors, developed or less developed countries, all countries), this second-order correlation coefficient is insignificant. The authors therefore reject the unbalanced growth hypothesis that countries which emphasized high-linkage sectors were able to achieve higher growth rates than countries that emphasized low-linkage sectors. However, in further analysis covering 13 manufacturing sectors in 34 countries, the authors confirm a "balanced-growth" version of the linkage hypothesis (details below): conformance across sectors to a particular imbalance pattern defined by sectoral linkage coefficients leads to high growth.

Yotopoulos and Nugent's analysis raises several questions.[6] First, it assumes that a high linkage coefficient implies a high growth rate for that sector. It is unclear why this should be the case. If, at the starting point, the economy were perfectly balanced—with sector-specific *levels* of output value—then one would expect all sectors to grow at the same *rate*, independent of linkage coefficients. A one-unit absolute increase in output of a high-linkage sector may call forth a many-unit absolute increase in output of other sectors, but the relative increase in output value is the same across sectors. In an unbalanced economy, a sector with a high-linkage coefficient may have a relative *low* growth rate compared to the growth rates of *underdeveloped*, other sectors where it may call forth, perhaps after crossing a threshold, a many-unit absolute increase from a low base.[7]

This also affects Yotopoulos and Nugent's "balanced growth version," where they hypothesize an optimum degree of imbalance. They define a country's "imbalance index" based on the squared deviations of sectoral growth rates from the weighted economy-wide growth rate, where the weights are the sectoral linkage coefficients entered multiplicatively; the squared deviations are then weighted by the sector's share in the country's GDP and averaged across sectors.[8] Taking the square root and standardizing (dividing) by the economy-wide growth rate yields the index of imbalance. This imbalance index, by design, assumes a low value, i.e., reflects a high degree of "balance," if there is a direct and positive correspondence between a sector's growth rate and the linkage coefficient. The favored correspondence, furthermore, is one where the ratio of each sectoral growth rate to the economy-wide growth rate exactly equals the sectoral linkage coefficient, in which case the value of the imbalance index is zero.

Second, Yotopoulos and Nugent's sectoral linkage coefficients measure the economy-wide change in gross output value given a unit-change in final demand for the products of the given sector. Hirschman (p. 108), when briefly discussing operational measures of linkage, also includes this measure. However, in laying out his argument for unbalanced growth he explicitly focuses on profit opportunities: "our aim must be to *keep alive* [emphasis in original] rather than to eliminate the disequilibria of which profits and losses are symptoms in a competitive economy" (p. 66, and similarly elsewhere in Chapter 4). I.e., the key to the linkage effect is profit opportunities, which, in a second step, lead to output growth. The linkage coefficients of Yotopoulos and Nugent provide no measure of the creation of profit opportunities.

Third, Yotopoulos and Nugent's analysis cannot take into account the potential role of the government. It is the government, with fiscal resources, that is in a good position to bring the benefits of high-linkage industries' positive externalities to fruition. The importance of government pervades much of Hirschman's book, and this includes direct government investment (much of Chapter 5). In the core chapter on linkages (Chapter 6), Hirschman writes that "the rationale for interference with the market mechanism and consumers' preferences is particularly strong in slow-moving economies where industrial growth is incipient" (p. 116).

A 1982 sequel by Nugent and Yotopoulos, introducing the concept of "normal" sectoral growth rates within measures of imbalance, again concludes slightly in favor of balanced growth in less developed countries (though not in centrally planned economies). But it also indicates the need to differentiate by country groups and to control for country specifics.[9]

The concept of backward and forward linkages has, otherwise, found a number of other uses in the literature. This includes, for example, an examination of the backward linkage effects from the demand for capital goods in Malaysia's tin, rubber and oil palm export industries on the development of a domestic light engineering industry (Thoburn, 1973), questions about the optimal sequence of privatization across eleven economic sectors of Poland based on linkage coefficients (Roberts, 1993), and the effect of changes in intra- and interregional backward linkage coefficients on gross outputs of European Union countries (Sonis et al., 1996). A number of studies calculate (national) linkage coefficients for China.[10] The literature does not consider linkage coefficients in the context of state involvement in the economy, nor do the linkage coefficients used in the literature measure the potential creation of profit opportunities.

2.3 Critique of the use of quantitative measures to test the unbalanced growth hypothesis

The concept of unbalanced growth evades a unique operational definition. Hirschman concluded from his own attempts at operationalization via linkage coefficients that "excessive reliance should obviously not be placed on these rankings, based as they are on a mental experiment subject to numerous qualifications" (p. 108).

One limitation is the assumption that a country's development started with the industry in question. For example, in the data on interdependence through purchases/sales that Hirschman presents, he finds the largest value for backward linkage in grain mill products, but acknowledges that the cultivation of wheat and rice is not necessarily the result of the establishment of wheat and rice mills.

Another limitation is the treatment of capital formation. Hirschman notes that the sectoral ranking of linkages does injustice to machinery and transport equipment, whose sales are largely to final demand (capital formation) and thus have low forward linkage coefficients. There is no essential difference between a stimulus from agriculture towards establishing a tractor assembly plant vs. an insecticide mixing plant. But while much of the output of the insecticide mixing plant is captured as linkage, that of the tractor assembly plant is not.

In the end, Hirschman appears somewhat more comfortable with backward linkages than with forward linkages. Backward linkages are likely to become effective as soon as domestic demand through new investment reaches a threshold. For forward linkages, he finds it "absurd to set up any model that would presume to indicate which kind of metal-fabricating industries would come into existence at what point in time in the wake of the establishment of a basic iron an steel industry" (p. 116).

Given such limitations, one may come to the conclusion that quantitative analysis of linkage effects cannot do justice to Hirschman's theory of unbalanced growth. Thus, McGilvray (1977), p. 56, writes: "It is regrettable that an original and valuable contribution to an understanding of economic development processes has been emasculated and oversimplified, a victim of the tendency to subordinate economic hypotheses to the restrictive requirements of elementary regression and correlation analysis. Thus measures of linkage have been reduced to the mechanical computation of index numbers."

The critique seems two-fold. A first aspect concerns the reduction of a book-length theory of unbalanced growth to an argument about linkages. The issue of linkages is one element of a multitude of insights into economic development. It is, thus, not possible to conclusively test the theory of unbalanced growth by testing just one element of it. One could further argue that the term "unbalanced growth" itself is ambiguous. Does "unbalanced growth" mean that different sectors grow at different speed? Or does it mean that the level of development of one sector imposes a (slight/significant/severe?) constraint on the further development of another sector? Or should "unbalanced" be reduced to "differences in linkage coefficients across sectors" (which would seem too narrow an interpretation of Hirschman's work)?

The second aspect of the critique concerns the measurement of linkages. There is no obvious choice of how to operationalize the concept of linkages. Does that mean we should abandon all attempt at operationalization? If we did, would that not render Hirschman's work a non-falsifiable hypothesis, or at least a hypothesis that can only be discussed in impressionistic terms? Some seem to have despaired of the intractability of "unbalanced growth" and, more generally, of the writings of the early development theorists. Thus, Krugman (1994) speaks of the "fall" of development economics because "high development theorists" (and he specifically refers to Hirschman) could not make the transition to "expressing their ideas in the kind of tightly specified models that were increasingly becoming the unique language of discourse of economic analysis" (p. 40).

Hirschman appears to have outlined his theory of unbalanced growth and the issue of linkages with policy implementation in mind. A non-falsifiable hypothesis would scarcely be justified as an analytical tool informing development policy. Hirschman himself points the way by suggesting a (simplistic) linkage indicator based on input-output tables—and then cautioning against "excessive reliance" on rankings based on linkage coefficients.

The approach here is to focus on two specific elements of the unbalanced growth theory and to test them using Chinese data: to what extent do linkage effects impact on economic growth, and to what extent does the Chinese government consider linkage effects in decisions on the distribution of state ownership across sectors? The analysis is limited to the linkage aspect of the unbalanced growth theory and the findings are valid for the chosen operationalization of linkages.

3. Linkage indicators

There are a number of options for linkage indicators. Miller and Lahr (2001) provide an overview. This paper proceeds with five different sets of linkage indicators. Linkage indicators come with technical limitations that are discussed in Appendix A.

The typical question asked in input-output analysis is how gross output value across the economy changes in response to a particular sector's change in final demand? If one assumes a constant returns to scale technology, the intermediate flows X_{ij} from sector i to sector j can be expressed as a share of gross output value of sector j, X_j, in form of input coefficients (or "technical coefficients") $a_{ij} = X_{ij} / X_j$. Replacing the X_{ij} in the input-output table (Figure 1) by $a_{ij} * X_j$, the system of row equations becomes, in matrix notation,

$\mathbf{A}\ \mathbf{x} + \mathbf{y} = \mathbf{x}$, or

$\mathbf{x} = (\mathbf{I}\text{-}\mathbf{A})^{-1}\ \mathbf{y}$,

where **x** is the column vector of sectoral gross output values ($X_1, \ldots, X_n$), **y** is the column vector of final demand ($Y_1, \ldots, Y_n$), **A** is the (n x n) matrix of input coefficients a_{ij}, and **I** is the (n x n) identity matrix. For a given final demand vector, gross output value of all sectors follows.

[Figure 1 about here]

Alternatively, with a constant proportion of sector i's *sales* going to sector j, The X_{ij} can be expressed using output coefficients (or "allocation coefficients") $b_{ij} = X_{ij} / X_i$. The system of column equations becomes, in matrix notation,

$\mathbf{x}'\ \mathbf{B} + \mathbf{w}' = \mathbf{x}'$, or

$\mathbf{x}' = \mathbf{w}'\ (\mathbf{I}\text{-}\mathbf{B})^{-1}$,

where **w**' is a row vector of sectoral value added ($W_1\ W_2 \ldots W_n$) reflecting, for each sector, the value of all primary inputs, and **B** is an (n x n) matrix of constant output coefficients b_{ij}. For a given vector of primary inputs, gross output value of all sectors follows. In the interpretation of Dietzenbacher (1997), the Ghosh inverse $(\mathbf{I}\text{-}\mathbf{B})^{-1}$ captures the change in output values in response to changes in the *prices* of primary inputs.

The five different sets of linkage indicators used in this paper are summarized in Table 1. The first set reflects Hirschman's first operational definition, with forward linkages of sector i defined as the proportion of total output of sector i that does not go to final demand (FL(1)), and backward linkages as the proportion of purchases from other industries in sector i's total inputs (BL(1)). Feedback effects (i.e., indirect effects) between sectors are not captured.

[Table 1 about here]

The second operationalization consists of what Hirschman called a "more refined measure:" backward linkage is measured as the column sum of the Leontief inverse $(\mathbf{I}-\mathbf{A})^{-1}$ and forward linkage as the row sum of the Gosh inverse $(\mathbf{I}-\mathbf{B})^{-1}$. This backward linkage indicator, BL(2), captures both the direct and indirect effects of a one-unit increase in final demand for the products of sector j on the output of all sectors; it includes the initial effect (the one-unit increase in output of sector j that reflects the one-unit increase in final demand for sector j's output). However, it suffers from the inclusion of some forward linkage effects.[11] Similarly, FL(2), which measures the impact of a one-unit change in the value of primary inputs on total output of each sector, suffers from the inclusion of some backward linkage effects. Furthermore, a "joint stability" problem applies in that if the A-matrix were constant over time, the B-matrix cannot be constant over time, and vice-versa (Cella, 1984).

The third set of linkage indicators comprises Cai and Leung's (2004) Leontief Supply-Driven multiplier (LSD) and Gosh Supply-Driven multiplier (GSD).[12] The LSD measures the total output change caused by a one-unit change to sector i's *output* and no change in other sectors' final demand, where equation i is extracted from the (Leontief) model; this is the backward linkage. (The mathematical setup described above is not elaborate enough to derive Cai and Leung's multipliers, or any of the following linkage indicators; these require a split matrix.) The GSD measures the total output change caused by a one-unit change to sector i's output (equivalently, input) and no change in other sectors' primary inputs, where equation i is extracted from the (Gosh) model. The LSD and GSD multipliers are derived using (i) the hypothetical extraction method (with no overlap between the backward and forward linkage coefficients, and the intra-sectoral linkage a_{ii} excluded), (ii) the Leontief inverse for backward linkages and the Gosh inverse for forward linkages (so that the backward and forward linkage indicators are defined symmetrically), and (iii) uniform output shocks (to avoid the implication of proportional shocks which imply the larger the sector, the larger the linkage).

The fourth linkage indicator, Heimler's (1991) index of vertical integration (INT), is best explained with reference to the LSD, i.e., to the total output change caused by a one-unit change in sector i's output: the initial one-unit change in sector i's output is not counted with the total output change, and the total output change is turned into value added (using sector-specific ratios of value added to gross output value) and divided by the original one-unit change in sector i's output now also turned into value added. I.e., this index of vertical integration measures the value added generated by sector i, outside sector i, per unit of value added in sector i.

A fifth linkage indicator is the total linkage indicator (TL) in Miller and Lahr's (2001) case of total extraction of one sector. It is based on the question of by how much an economy's total output in all sectors, *excluding* sector i, would decrease if sector i were absent, i.e., if the i^{th} row and column of the intermediate flow matrix as well as gross output value of sector i are set equal to zero, and the needs for products of sector i (in intermediate use of the non-i sectors or in final demand) are met solely through imports. In order to obtain a measure of the relative size of the loss, the loss of output in all sectors (excluding sector i) is related to the original output of sector i. This index measures the gross output value outside sector i created by a one-unit increase in sector i gross output value. It appears the most meaningful measure of linkage for examining the unbalanced growth hypothesis because it captures all linkage effects, backward and forward (and direct and indirect), without any double-counting. The distinction between backward and forward linkages may yield additional insights, but what matters primarily is the total effect, especially when backward and forward linkages cannot be meaningfully summed up.[13]

The linkage indicators will later be subjected to two further manipulations. First, to compare the potential for linkage effects across geographic entities, a comprehensive measure of linkage in form of a "coefficient of interdependence" is calculated for each locality. For a particular linkage indicator, the local coefficient of interdependence is the weighted sum of all sectoral linkage coefficients, with as weights the sectoral output values or final demand values.[14] An economy with an, on average, higher coefficient of interdependence would appear to have more possibilities for backward and forward effects to spread. Second, a measure of variation, such as the coefficient of variation, can be calculated for sectoral linkage coefficients. Given an equal depth of sectoral interdependence, linkage coefficients of approximately equal value across sectors may have a different impact on growth than linkage coefficients that differ across sectors.

A crucial departure of this paper from the practice in the linkage literature is the translation of all linkage indicators into “profit linkage” indicators in order to capture Hirschman’s focus on the creation of profit opportunities. The output linkage coefficient of a particular sector measures how a unit increase in final demand or gross output in one particular sector affects *output* across the sum of all sectors (possibly excepting the original change, or the sector in which the original change occurred). In contrast, the profit linkage coefficient measures how a unit increase in final demand or gross output in one particular sector affects *profit* across the sum of all sectors. By, before summing the effects across all sectors, multiplying the output effect that a particular sector experiences by its ratio of operating surplus (the national income accounting measure of profit) to gross output value (or value added, depending on linkage indicator), the in the literature typically used output linkage coefficient turns into a profit linkage coefficient. Data on operating surplus are available in the input-output table; the operating surplus is one of the four components of value added (primary inputs).[15]

4. Evidence

In a first step, the linkage coefficients are calculated. Second, across sectors, linkage coefficients are correlated with ownership data. Third, economic growth is related to linkage coefficients and ownership data.

4.1 Linkage coefficients

4.1.1 Input-output data

At the national level, input-output tables were compiled in 1981, 1983, 1985, 1987, 1990, 1992, 1995, 1997, 2000, 2002, and 2005. Not all of these are publicly available, and some of them draw heavily on the table of a few years earlier. The most independently compiled tables are those of 1981, 1987, 1992, 1997, and 2002. Provincial input-output tables appear to be compiled equally regularly but these are rarely made public; some of the early provincial input-output tables that are available in the West are stamped “secret” (*juemi*).[16] Those that have been published tend to come with only a small number of sectors (at the extreme, just six sectors). At the regional level, an inter-regional input-output table is available for 1987 with seven regions and nine sectors (Ichimura and Wang, 2003), and a multi-regional input-output table for 1997 with eight regions and 17 sectors (SIC, 2005).

With the province as the unit of analysis, provincial input-output tables would be ideal. But given the scarcity of these tables, the only choice is between a national table with the linkage coefficients applied equally to all provinces, or regional tables with the linkage coefficients applied equally to all provinces in a region. A regional table at least allows variation in linkage coefficients across regions. The multi-regional input-output table for 1997, with eight regions and 17 sectors, is used here; the 1987 inter-regional input-output table comes with too few sectors to be useful for the analysis here.[17] The year 1997 is crucial: if the state made a strategic choice to retain state ownership in high linkage sectors, this decision would come to fruition in the SOE reform program of 1998-2000 and the impact on growth should be visible in the subsequent years. The 1997 data may also be some of the best available because 1997 is a year when the national input-output table was compiled relatively independently; the regional input-output table is an outgrowth of the national table (SIC, 2005, p. 6).

Special consideration is necessary for inter-regional and international trade flows. If final demand for the goods and services of a particular sector in a particular region increases—whether through an increase of final demand in this region, in other regions, or abroad—some of the new final demand translates into output growth in other regions or abroad through imports of intermediate inputs into this region from other regions or abroad. Similarly, if final demand in another region or abroad increases, this may result in an increase of intermediate inputs provided by this region to the other region or abroad.

In the manipulation of the multi-regional 1997 input-output table below, inter-regional trade flows and international exports are treated as domestically non-competitive. This means that a region's input coefficients are net of this region's demand for intermediate inputs supplied by other regions, and net of the supply of intermediate inputs from this region to other regions. I.e., the regional input coefficients capture the impact of a change in 'final demand for the products of this region' on '*production in this region*' (only); they also ignore the impact of a change in 'final demand for the products of another region' on 'production in this region.'

This is desirable for the purpose of the analysis. The objective is to find out if the local state strategically retains or promotes state-ownership (within this province) in sectors which, through a high linkage effect, promote economic growth in this region, not in other regions. The local state is likely to reach its ownership decisions without coordinating with other regions about their potential demand and production changes and the ensuing impact for this region. This does, however, ignore the possibility for the local state to consider expansion into high linkage sectors to substitute local production for current imports from other regions.

A *national* decision-maker could be interested in the effect of its decisions on national production, in which case the trade flows between regions should be explicitly considered. With no data available on central vs. local state ownership by sector within each province, which would allow separate national vs. provincial analysis, the interpretation here is in favor of local decision-making.[18] This is in line with a history of cellularism, reform measures endowing local governments with decision making power, predominantly local rather than central state investment, and the large-scale abandonment by the center of control over SOEs.[19]

The treatment of international imports differs. Imports of this region from abroad are treated as competitive. I.e., a change in the final demand for the products of this region will not lead to any change in imports from abroad but will lead to a corresponding change in the production in this region or another region. If in the real world some imports from abroad are non-competitive, i.e., this region cannot produce these imports on its own (or obtain them following a past pattern from another region), then the linkage coefficients calculated here wrongly attribute these necessary imports to local production. This is a limitation of the data and cannot be remedied.[20]

4.1.2 Linkage values

Based on the 1997 multi-regional input-output table, the values of the five sets of linkage indicators—eight distinct indicators—introduced above and summarized in Table 1 can be calculated for each of the 17 sectors in each of the eight regions. Both output-linkage coefficients and profit-linkage coefficients are calculated.

Two questions to ask of the data are the following. First, in any *one region*, do the linkage patterns across sectors differ between linkage indicators? If they do not differ much, then one representative linkage indicator suffices for the remainder of the analysis. Second, for *one specific linkage indicator*, do the values differ across sectors and across regions? If they differ across sectors, the unbalanced growth hypothesis suggests that some sectors should attract more state attention than others. If they further differ across regions, the unbalanced growth hypothesis suggests different distributions of state ownership (across sectors) in different provinces.

The linkage patterns of different linkage indicators across sectors are rather similar for the different regions. The region Beijing-Tianjin serves as illustration (Table 2). In the case of output linkage indicators, the four different backward linkage indicators—where the index of vertical integration, INT, is a backward linkage indicator, as is Cai and Leung's LSD—tend to be positively correlated with each other, as are the three different forward linkage indicators.

[Table 2 about here]

There is no prior expectation for the relationship between backward and forward linkage indicators. With few exceptions, backward and forward linkage indicators are negatively correlated across sectors; this pattern holds even when the backward and forward linkage indicators are from different sets of linkage indicators. It would thus be plausible to proceed with one representative backward linkage indicator and one representative forward linkage indicator.

Two of the four backward linkage indicators are positively correlated with the total linkage indicator (TL), and two of the three forward linkage indicators negatively. The TL thus appears to be capturing something different from the backward and forward linkage indicators.

In the case of profit linkage indicators, no patterns are apparent (Table 2). While some correlations are significant, the correlation is not always positive for the backward linkage indicators, and some forward linkage indicators are positively correlated with the backward linkage indicators. One backward linkage indicator is positively correlated with the TL.

The findings for the profit linkage indicators make it difficult to narrow down the choice of indicators. Fortunately, what is of interest in the following analysis is less the distinction between backward and forward linkages than the total linkage effect of a sector, and the focus is therefore on the TL. Hirschman thought that backward linkages operate more reliably than forward linkages. Perhaps they then enter policy considerations more readily. Heimler's INT and Cai and Leung's LSD are the two most comprehensive measures of backward linkage and will at times be drawn upon below, as will be the GSD for forward linkages.

To answer the second question, if the values of a specific linkage indicator differ across sectors and across regions, Table 3 and Table 4 report the TL coefficients, Table 3 for the total output linkage indicator, subsequently labeled "TOL" (i.e., the TL of Table 1), and Table 4 for the total profit linkage indicator "TPL" (i.e., the TL of Table 1 turned into a profit linkage indicator).

[Table 3 and Table 4 about here]

TOL coefficients vary substantially across sectors (Table 3). For example, in the Northeast region they vary from 0.417 (mining) to 1.517 (construction); the TOL coefficient for mining implies that a one yuan change in output of the sector mining comes with a 0.417 yuan change in output in all other sectors of the economy. The coefficient of variation—of TOL coefficients across sectors in one region—ranges from 0.304 in the Northeast to 0.506 in the Central region.

Weighting sectors by their share in value added (in this region) leads to very similar results. The substantial variation of TOL coefficients across sectors within one region implies that if the unbalanced growth hypothesis holds for China, state ownership should vary across sectors.

The patterns of TOL coefficients across regions are similar. Correlation coefficients between any two regions are positive and significant at the 0.1% level (1% level in one case). The unbalanced growth hypothesis then predicts similar patterns of state ownership across provinces.

Within any one region, the TPL vary equally much across sectors as the TOL (see the coefficient of variation in Table 4). The linkage effect is much lower for the TPL because operating surplus is just one of four component of value added, which in turn together with intermediate inputs adds up to gross output value. On average, a one yuan output change in a particular sector creates changes of around 0.04 yuan in operating surplus in the other sectors. (Weighting sectoral TPL coefficients by value added or operating surplus makes little difference to the average sectoral TPL of a region.)

The Central region is a special case: output expansion in any one sector in the Central region has negative profit effects for the aggregate of all other sectors in the Central region. This does not seem plausible and raises questions about data quality. But going back to the raw data, the fact that out of the 17 sectors three ("other manufacturing," "utilities," and "other services") have positive operating surplus precludes the conclusion of systematic data errors. Below, in quantitative analysis that involves the TPL, the Central region will be controlled for.

In the case of the TPL, the patterns of linkage coefficients across sectors are not uniformly similar across regions, unlike for the TOL. In half of all combinations of regions, the correlation coefficient is positive and significant; in all seven combinations that involve the Central region it is negative (and significant in six), and in the remaining seven combinations it is positive and insignificant. In other words, there is less uniformity in sectoral TPL across regions than is the case for the TOL. Should the unbalanced growth hypothesis hold for China, this suggests not only strategic variation of state ownership across sectors but also across regions. However, more regional uniformity is found when regressing the region-and sector-specific TPL on region and sector dummies; all regions are similar except for Central and Southwest. The typical sector differs from approximately half of all other sectors. (In the case of the TOL, in regressions all regions except the Northeast and the Southeast are similar, while most sectors differ.)

Repeating the analysis for the LSD, INT, and GSD—using both output and profit linkage coefficients—the patterns of linkage coefficients across any two regions are again similar (not reported in the tables). Using output linkage coefficients, the correlations tend to be weaker for the LSD and INT, and stronger for the GSD; using profit linkage coefficients, the correlations tend to be stronger throughout.[21] The coefficients of variation in the case of the INT and GSD are smaller for the output linkage coefficient and larger for the profit linkage coefficient.

4.2 State ownership

4.2.1 Ownership data

Ownership data are available primarily for industry. Value added data by industrial sector became first available in 1993, but the 1993 values are of dubious quality (Holz, 2003, p. 23) and are therefore not included in the analysis below. The data by industrial sectors, similar to the practice in other countries, do not cover the universe of industrial production units. In China, sectoral data cover the "directly reporting industrial enterprises."

The analysis focuses on one three-year period prior to the date of the input-output table and two subsequent three-year periods. The second period of analysis, 1997 through 2000, captures the full brunt of the SOE reform program begun in 1998 (and ending in 2000).

The analysis is potentially encumbered by statistical breaks in the data. In 1998, two relevant changes occurred. First, the statistical category "SOEs" was abandoned in favor of a new category "state-owned and state-controlled enterprises" (SOSCEs) to include those SOEs which, by turning into a shareholding company (possible since 1992/93), had escaped the pre-1998 category "SOEs." But the (unknown) extent of state-owned shareholding companies in 1997, missing from the "SOE" category, was likely small. The label "SOEs" will be retained in the following to cover the SOE category before 1998 and the SOSCE category since then.

A second change in 1998 is a re-definition of directly reporting industrial enterprises. But the change in the coverage of directly reporting industrial enterprises is only one, possibly minor aspect of an annually changing pool of enterprises. Every year, some enterprises enter or exit the group of directly reporting industrial enterprises, independent of the criterion for inclusion.

Another relevant change occurred in 2003 with a revision of the sectoral classification scheme. But a relatively reliable aggregation to the level used in the input-output table remains possible. Details on these statistical breaks are provided in Appendix B.

The analysis does not extend further into the future for two reasons. First, ideally the analysis stays close to the date of the input-output table. Second, starting in 2005 provincial data on the value added of directly reporting industrial enterprises, and separately, SOEs within this group, become increasingly scarce. The logic behind this change in publication practices may be that enterprise accounts do not include a variable "value added." Value added is a national income accounting concept. (Enterprise accounts include data on sales revenue and inventory changes, and thereby indirectly on gross output value.) Given the expansion of the industrial sector over time, the provincial statistical bureaus may have decided not to put any effort into calculating and reporting detailed value added data any more.

4.2.2 Linkage and state ownership

Table 5 presents the correlation coefficients across the 13 industrial sectors between the sectoral linkage coefficients (of a region) and the sectoral output shares of the state (of a province within that region). If China's government were to focus state investment on sectors with high linkage effects, the share of state ownership in the output of a particular sector should be positively correlated with the sectoral linkage coefficient. As Table 5 shows for the TOL and TPL, province by province, and region by region, for the years 1994, 1997, 2000, and 2003, this is not the case. Very few of the correlation coefficients are significant, and all that are significant are negative (as most non-significant ones are). This suggests that the state in these provinces in these years accounts for a large share of output in sectors with low linkage coefficients.

[Table 5 about here]

The results are very similar if, for each province at a time, *changes* in the sectoral shares of SOEs over any one of the three periods (in relative or absolute terms) are correlated with the sectoral linkage coefficients (not reported in the table). They are also very similar if TOL and TPL are correlated, across sectors, with the ratio of sectoral SOE value added to all SOE value added (i.e., if the sectoral SOE output share is not measured relative to all directly reporting industrial enterprises of the same sector, but to the sum of all SOEs across all sectors). The correlation coefficients tend to be negative but not significant except in a few instances.

But perhaps the Chinese government was only aware of the backward linkages (that are more likely to take effect than the forward linkages, as Hirschman argued)? Repeating the calculations underlying Table 5 for the LSD, INT, and GSD linkage indicators yields near-identical results as in the case of the total linkage coefficient.

These results contradict the unbalanced growth hypothesis. If the state wanted to promote economic development, one would expect it to retain a large ownership share in high linkage sectors. Is it possible that in the case of China high linkage effects do not come with rapid economic growth, and the state, if it is interested in economic growth, then fares well to stay away from high linkage sectors? Or is the link between ownership and degree of linkage of a sector more subtle in that other factors need to be controlled for?

4.3 Linkage, state ownership, and real GDP growth

To answer these questions, provincial real GDP growth is regressed on (provincial) industry-wide total linkage coefficients, ownership variables, and interactions of total linkage and ownership variables. Linkage coefficients cover the thirteen industrial sectors out of the total of seventeen sectors because sufficient ownership information is available only for these thirteen industrial sectors. The industry-wide total linkage coefficient of a province, the "coefficient of interdependence," is derived as explained in section 3 above. It is the weighted sum of all thirteen industrial sector linkage coefficients of a particular region, with as weights the corresponding industrial sector value added (of the directly reporting industrial enterprises) in that province. The industrial sector linkage coefficients are of 1997, the weights are those of the first year of each period examined.

The regression results are reported in Table 6. Each variable used in regressions is initially included with coefficients estimated separately for each of the three periods; if the coefficients do not exhibit a significant pattern, the distinction between periods is dropped.

[Table 6 about here]

4.3.1 Findings

The first regression examines the impact of provincial industry TOL and the coefficient of variation of TOL (where deviations are weighted by sectoral value added) on provincial economic growth; dummies for the first and the third time period are also included. Neither TOL nor its coefficient of variation are significant. Splitting TOL into the three periods makes no difference (not reported in the table).[22]

In a second regression, two sets of explanatory variables are added. One is the share of SOEs in the value added of the directly reporting industrial enterprises at the beginning of each period (summed sectoral shares with as weights the provincial first-year sectoral value added of the directly reporting industrial enterprises); the other is its coefficient of variation. A clear pattern of the impact of ownership on provincial economic growth, controlling for TOL, emerges: in the first period, 1994-97, state ownership has a significant negative impact on provincial economic growth; by the second period, 1997-00, the impact is still negative but only half the size of the first period's value, as well as less significant, while by the third period all ownership impact has disappeared. Provincial economy-wide TOL has a negative impact on provincial economic growth, which is unexpected. One would expect that the higher the economy-wide total output linkage coefficient, the higher provincial economic growth.

With the mean TOL value approximately equal to the mean SOE share value (unweighted means of 0.54 and 0.64 across provinces and periods), the two variables have approximately the same negative impact on provincial economic growth in the second period, 1997-2000, while in the first period, 1994-97, the SOE share has twice the impact of the TOL. The effect of the SOE share is independent of that of TOL; if TOL and its coefficient of variation are omitted (third column of Table 6), the coefficients and significance levels of the SOE share remain unchanged. In all three regressions, the large positive size of the constant and period dummies more than makes up for the negative impact of TOL and the SOE share.

Switching to TPL instead of TOL (fourth column of Table 6) yields the expected sign: the higher total profit linkage, the higher provincial economic growth. TPL typically explains 2-3 percentage points of provincial economic growth (with an unweighted mean TPL coefficient across provinces and periods of 0.02). Because the Central region has negative sectoral TPL coefficients, a dummy variable for the Central region's provinces is included in the regression; it has the right sign and size needed to make up for the in this case negative TPL effect. If the SOE share is included (fifth column of Table 6), its coefficient has the same size and signs as previously in the case of TOL and does little to subtract from the TPL effect; instead, it raises the value of the positive constant and period dummies.

Across all regressions, the coefficients of variation of TOL, TPL, and the SOE shares are insignificant. The degree of equality in the distribution of linkage coefficients (or SOE shares) across sectors makes no difference to provincial economic growth.

The regressions reported so far suggest a positive effect of regional economy-wide TPL on provincial economic growth, while an initially significant negative effect of state ownership turns insignificantly positive by the third period, 2000-03. In a sixth regression, TPL and state ownership are interacted within each province. The newly constructed variable "TPL-SOE," for each province, sums across industrial sectors the (regional) TPL of a sector weighted by that sector's SOE value added share in provincial economy-wide industrial SOE value added. A high value of TPL-SOE means that SOEs focus on high-linkage sectors. The estimated significant coefficients suggest that a SOE focus on high-linkage sectors is indeed beneficial for provincial economic growth.[23] On average, the TPL-SOE interaction effect contributes two percentage points to provincial economic growth. (The unweighted mean value of TPL-SOE across provinces and periods is 0.02.)

When the SOE share is included in the regression (seventh column in Table 6), the TPL-SOE interaction effect continues to hold in the second and third period. However, once the TPL is itself included and competes directly with the TPL-SOE interaction effect, the interaction effect between TPL and SOEs disappears (eighth and ninth column in Table 6, with and without the SOE share), while the TPL effect is less significant than it is when the TPL-SOE interaction effect is excluded. The R^2 continues to increase.

In sum, on their own, either TPL or TPL-SOE have the expected consistently significant and positive impact on provincial economic growth. But once they compete directly, the pure TPL effect wins out while multicollinearity appears to erode the individual significance. The pure SOE effect in form of the SOE share continues to exert its negative impact in the first (and possibly second) period before disappearing in the third period.[24]

4.3.2 Robustness checks

The regression results reported in Table 6 come with residuals that are normally distributed throughout (Jarque-Bera test at the 5% significance level). Residuals are homoscedastic (White heteroscedasticity test at the 5% significance level) except in the second regression; switching, in the second regression, to robust standard errors, these are *lower* than those reported in Table 6. The Ramsey Reset test with three fitted values does not indicate model misspecification for any of the regressions.

The regressions can be run in a number of variations. First, while SOE share values can only be calculated for the industrial sectors, the TPL can be calculated across *all* seventeen sectors within a region (weighting sectoral TPL coefficients by sectoral value added). Regressing provincial economic growth on a constant, two period dummies, and the *regional* economy-wide TPL yields similar results as above with industry TPL coefficients, namely positive TPL coefficients in all three periods, with those of the first two periods significantly different from zero.[25] I.e., high values of TPL imply high rates of economic growth. The coefficient of variation of regional economy-wide TPL is negative, but significant only in the first period. (In a similar TOL regression, all coefficients are insignificant.)

Second, the TPL-SOE interaction effect can be augmented by the real growth rate of SOE value added. The TPL-SOE interaction in growth form is the sum across industrial sectors of the following triple product: regional sectoral TPL times provincial sectoral SOE real growth rates times a sectoral weight in form of 'provincial SOE value added in this sector divided by provincial SOE value added in all sectors.'[26] This interaction growth rate also comes with a positive coefficient which, however, is significant only in the second period (and only barely so). Once other control variables are included (SOE share, TPL), as above, all significance vanishes. In other words, in the second period, SOE growth may focus on high-linkage sectors, but the effect is far from strong and disappears once the pure provincial industrial SOE share and the pure provincial industrial TPL are taken into account.

Third, the analysis could focus on those sectors in a region that come with the highest TPL coefficients. Selecting, in each region, the three industrial sectors with the highest TPL coefficients (marked with a "+" sign in Table 4), the share of these combined three sectors in provincial industrial value added has a positive impact on provincial economic growth, while the share of SOEs in these three sectors has a negative impact. The growth rate of SOE real value added in these three sectors has practically no impact on provincial economic growth; the same holds if the SOE growth rates of each of the three sectors are weighted by linkage coefficients and SOE value added. If there were a pattern, it is too weak to become apparent with the available number of observations. Once the provincial industry TPL coefficient is included in the regression, it dominates all other results. These findings again parallel those above.

Additional variables can be included in the regression, from development level (GDP per employee, share of agriculture in GDP or employment) to capital intensity, schooling, infrastructure (railway or highway network), and the state share in the always high-linkage construction sector (which, because it is not an industrial sector, is not included in the industry-based analysis above). Many of these variables are insignificant, and some are potentially endogenous. Including them in the regression does not qualitatively change the core results.

Measures of capital and labor growth are not included as regressors because they are either intervening or endogenous variables. The profit opportunities created by linkages lead to the employment of capital and labor, which then leads to provincial real GDP growth (capital and labor as intervening variables). The profit opportunities created by linkages can also be viewed as causing new output to be pursued, i.e., to provincial real GDP growth, which then implies the purchase of more capital goods and the hiring of more labor.[27]

4.3.2 Discussion

Why does the Chinese state not strategically retain (or increase) state ownership in high linkage sectors when high linkage sectors clearly have a positive impact on growth? First, perhaps the state is interested in making good use of linkage effects, but not through SOEs. An alternative measure of state involvement across sectors is current period investment. If the government were to focus on high-linkage sectors, then the sectoral linkage coefficients should be correlated with the state's sectoral investment policy.

A set of provincial-level sectoral investment data by ownership is not available. At the national level, what can be calculated are (i) the share of the state in all investment in a sector, and (ii) the share of a particular sector in the state's economy-wide investment. Either set of shares can then be related to the region-specific linkage values. For the period 1994-2003, sector-specific national investment data are not available; investment was classified as capital construction vs. technological updating, with no ownership breakdown. In the most recent year, 2008, neither of the two measures of the state's investment patterns across sectors is correlated with any of the eight regional TPL patterns at the 10% significance level, except for the first measure in the case of the Central and the Northwest region. Pursuing other measures of profit linkage, there is virtually no correlation for the LSD and GSD; correlation can be found only for the INT, for five to six of the eight regions, mostly at the 10% significance level. (The results for output linkage indicators are similar.) Except for the case of the INT, the results are unambiguous: state investment does not focus on high-linkage sectors.

In an extension of the investment argument, is it possible that the state uses assets as a policy tool? One of the tasks of the State Asset Supervision and Administration Commission is to protect and increase state assets, and local governments and their respective asset supervision and administration commissions may pursue similar objectives. Indeed, in 2003, the final year of analysis, using the data on the thirteen industrial sectors, the state's shares in sectoral assets at the national level is positively correlated with the sectoral TOLs for all eight regions, at the 5% or 1% significance level. In the case of the TPL, the same holds for five regions. (The results are weaker if the asset variable is the sectoral share in the state's total assets, and there is almost no correlation for the INT, LSD, and GSD.) In contrast to the investment data, thus, the existing distribution of state assets suggests some attention by the state to high linkage sectors. However, since asset values reflect cumulative past policies rather than current policies, this finding has only limited meaning for the question of strategic SOE withdrawal considered here.

A second alternative hypothesis is that industrial policy considerations in China are made along political rather than along economic lines. Thus, the tenth Five-Year Plan (2001-05) distinguishes between five groups of industrial sectors (SETC, Oct. 2001).

- Military industry remains overwhelmingly state-owned. The military industry may be captured in the regional input-output table by the sector "others," a sector that is not a high-linkage sector (Table 3, Table 4).
- In public goods industries and services, as well as in natural monopolies, the state should hold a controlling stake. Utilities, in terms of TPL, are high-linkage sectors (among the top three industrial sectors with the highest linkage) in two regions.
- SOEs should continue to hold a dominant position in industries of great importance for the "strength of the nation," such as the petroleum, automobile, telecommunications, machine building, and high technology industries. These sectors match the high-linkage categories frequently.

- The state should play a driving function in key high technology areas. Presumably, the most relevant sector in the regional input-output table is the electric machinery and electronic communication equipment sector, with a high TPL in one region.
- In other industries, the state is not assigned any specific role.

The match between these broad industrial policy outlines and linkage coefficients appears random. National industrial policy as formulated in the Five-Year Plan does not conform to an unbalanced growth strategy that focuses on linkage effects.

The previous, ninth Five-Year Plan (1996-2000) offers no specific sectoral instructions for SOEs. It is primarily concerned with the introduction of the “modern enterprise system” and includes the reorganization of SOEs to prevent the loss of state assets, and a strengthening of enterprise management.[28] This preoccupation with survival suggests a third alternative to the unbalanced growth hypothesis: re-orientation towards profitability, or profit maximization.

SOEs belong to one of four levels of government from county to central level. The government at each level is responsible for its SOEs. To adopt an economic development strategy for its SOEs that focused on linkages, each tier of the Party-state hierarchy would need to find such a policy more beneficial for the particular tier than simply striving for SOE profit maximization. Input-output tables are unlikely to exist at the county and municipal level. At the provincial level, input-output tables have been compiled for some provinces for some time, but Party-state policy makers may not be sufficiently familiar with input-output tables as planning instruments. Even if they were, each department within a government may wish to strive for profit maximization in its SOEs as long as it can extract substantial benefits for the department from doing so. Wong (2009, p. 932) notes that “official documents from the 1980s and early 1990s revealed no sustained discussion of how to identify areas or services where the government’s role could or should be reduced. … In the 1980s nearly all discussion was centered on reviving the profitability of SOEs.” At the enterprise level, SOE managers will pursue SOE profit maximization if that is the criterion for their evaluation, or if they otherwise derive benefits from profitability.

National level data for the industrial sectors in 2003 show that the state indeed focuses on sectors with high profitability. The state's share in sectoral value added is positively correlated at the 5% significance level with profitability of all directly reporting industrial enterprises in a sector (where profitability is measured as profit per unit of equity, or profit plus taxes per unit of equity). The same holds for the sectoral share in state value added in correlation with SOE profitability in a sector. Some sectors may enjoy high profitability due to state policies (such as on prices) rather than market forces, but the fact remains that the sectoral distribution of SOEs matches profitability patterns. In further examination, there is virtually no correlation between profitability of a sector (or profitability of SOEs in a sector) and the sectoral TPLs of the eight regions (or the profit linkage indicators of INT, LSD, and GSD). This conforms with the findings above of little evidence for a state focus on high-linkage sectors.

5. Conclusions

While the quantification of linkage effects in earlier literature has been unable to confirm Hirschman's unbalanced growth hypothesis, the new linkage indicators and method of analysis proposed in this paper unambiguously confirm the unbalanced growth hypothesis. The greater the degree of linkage in a Chinese province, the more rapid its economic growth. It is profit linkage that matters, rather than output linkage (the measure used in earlier development literature), and it matters for economy-wide growth.

In an extension, the distribution of TPL coefficients *across sectors* does not matter in the case of China. It is not the availability or unavailability of extreme profit-creating opportunities (high coefficient of variation of TPL) that impacts on economic growth, but the average degree of profit-creating opportunities (TPL) in the economy.

The response to the question if the Chinese state strategically retains (or increases) state ownership in high linkage sectors and thereby promotes economic growth is negative. The provincial state in China does not concentrate state ownership of enterprises in high linkage sectors. The extent to which SOEs are concentrated in high linkage sectors exerts a positive effect on provincial economic growth only if provincial TPL is not controlled for. This suggests that the SOE-linkage interaction effect on economic growth is weak or non-existent.

The impact of the share of SOEs in sectoral value added follows a distinct pattern across all variations of regressions. The SOE share has a consistently negative impact on economic growth in the first period (1994-97), less so or none in the second period (1997-2000), and none in the third period (2000-03). This pattern is similar to that identified by Hsieh and Klenow (2009) in their measurement of the effect of misallocation of resources across manufacturing firms on TFP. In 1998 through 2005, state-owned plants have an on average 40% lower within-industry TFP level than private domestic plants. No breakdown by year is offered. However, the authors identify a time trend for within-industry TFP *dispersion*. State ownership has a significant positive effect on within-industry TFP dispersion in 1998 and 2001 but no longer in 2005 (by when, as a figure shows, TFP of state-owned plants has increased drastically).

If the retention or expansion of SOEs were a profit-seeking rather than profit-creating undertaking, as the national-level evidence presented in the discussion suggests, then any justification of state ownership as a generator of economic growth *via linkage effects* is impossible. With the state consistently not making use of linkage effects via its SOEs, we do not have a measure of how fast economic growth would have been if the Chinese Party-state had chosen and managed to put in place a consistent economic development program. Perhaps the Party-state in China is incapable of organizing an overarching development program that goes beyond the pre-reform period's copying of Soviet industrialization measures and a focus on heavy industry, and its best response was to open up the economy to the private sector and competition. One piece of consolation for the beneficiaries of economic growth in China is that the seeming reliance on a market-based principle—profitability—means that at least by the third period SOEs no longer impede economic growth.

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Chinese names are rendered last name first, with the last name in capital letters.

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		Intermediate purchases of sector j				Sum interm. sales	Final demand				Sum final dem.	Gross output value
		1	2	…	n		Con.	Inv.	Exp.	Imports (neg.)		
Intermed. sales of sector i	1	X_{11}	X_{12}	…	X_{1n}	U_1	C_1	I_1	E_1	M_1	Y_1	X_1
	2	X_{21}	X_{22}	…	X_{2n}	U_2	C_2	I_2	E_2	M_2	Y_2	X_2
	…	…	…	…	…	…	…	…	…	…	…	…
	n	X_{n1}	X_{n2}	…	X_{nn}	U_n	C_n	I_n	E_n	M_n	Y_n	X_n
Sum int. purch.		V_1	V_2	…	V_n							
Primary inputs	L	L_1	L_2	…	L_n							
	D	D_1	D_2	…	D_n							
	T	T_1	T_2	…	T_n							
	S	S_1	S_2	…	S_n							
Sum prim. inp.		W_1	W_2	…	W_n							
Gr. outp. val.		X_1	X_2		X_n							

L: labor remuneration; D: depreciation; T: net taxes on production; S: operating surplus.

Con.: consumption; Inv.: investment (gross fixed capital formation); Exp.: exports.

W is value added. The sum of sectoral value added equals the sum of final demand (income approach GDP equals expenditure approach GDP).

Figure 1. Input-Output Table

Table 1. Linkage Indicators of Individual Sectors

1.	Hirschman	$BL(1)_j = \sum_i X_{ij} / X_j = \sum_i a_{ij}$	share of intermediate purchases in inputs of sector j
		$FL(1)_i = \sum_j X_{ij} / X_i = \sum_j b_{ij}$	share of intermediate sales in output of sector i
2.	Leontief inverse	$BL(2)_j = \sum_i \alpha_{ij} = j^{th}$ element of $e'(I\text{-}A)^{-1}$	total (economy-wide) output change due to one-unit change in final demand for sector j
	Gosh inverse	$FL(2)_i = \sum_j \beta_{ij} = i^{th}$ element of $(I\text{-}B)^{-1}$ e	total output (input) change due to one-unit change in value of primary inputs into sector i
3.	Cai/Leung (2004)	$LSD = BL(3)_i = 1 + \mathbf{e}' (\mathbf{I}\text{-}\mathbf{A}_{jj})^{-1} \mathbf{A}_{ji}$	total output change due to one-unit change in output of sector i
		$GSD = FL(3)_i = 1 + \mathbf{B}_{ij} (\mathbf{I}\text{-}\mathbf{B}_{jj})^{-1} \mathbf{e}$	total output change due to one-unit change in input of sector i
4.	Index of vertical integration (Heimler, 1991)	$INT_i = [\mathbf{v}' (\mathbf{I}\text{-}\mathbf{A}_{jj})^{-1} \mathbf{A}_{ji} X_i] / VA_i$, where v is a vector of sectoral ratios of value added to gross output value, and VA_i is value added of sector i	value added generated by sector i, outside sector i (in sector[s] j), per unit of value added in sector i
5.	Total linkage effect: Leontief – HEM	$\mathbf{e}'(\mathbf{x}_j - \mathbf{x}_j^R) = \mathbf{e}'(\boldsymbol{\alpha}_{jj} \mathbf{A}_{ji} \mathbf{H} \mathbf{y}_i) + \mathbf{e}'(\boldsymbol{\alpha}_{jj} \mathbf{A}_{ji} \mathbf{H} \mathbf{A}_{ij} \boldsymbol{\alpha}_{jj} \mathbf{y}_j)$ where $\boldsymbol{\alpha}_{jj} = (\mathbf{I}\text{-}\mathbf{A}_{jj})^{-1}$, and $\mathbf{H} = (\mathbf{I} - \mathbf{A}_{ii} - \mathbf{A}_{ij} \boldsymbol{\alpha}_{jj} \mathbf{A}_{ji})^{-1}$	absolute reduction in output outside sector i (in sector[s] j) if sector i is eliminated
		$TL_i = \mathbf{e}'(\mathbf{x}_j - \mathbf{x}_j^R) / X_i$	total output change outside sector i (in sector[s] j) due to one-unit output change in sector i

"Output" refers to gross output value; "total output" refers to gross output value economy-wide.
"e" denotes a column vector of ones.
The **A** (and similarly **B**) matrix is partitioned into row and column i vs. all other rows and columns (block) j, i.e., $\mathbf{A} = [\mathbf{A}_{ii}\ \mathbf{A}_{ij}\ ,\ \mathbf{A}_{ji}\ \mathbf{A}_{jj}]$.
For the definition of all other variables see the text.
For the derivation of the LSD and GSD see Cai and Leung (2004). The authors point out that, following Miller and Blair (1985, p. 328), a simpler way to calculate LSD is to obtain a modified Leontief inverse. The modified Leontief inverse is obtained by dividing each element α_{ij} in $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ by the diagonal element in its column (α_{ii}) to obtain $(\mathbf{I}\text{-}\mathbf{A}^*)^{-1}$ and then calculating the i^{th} column sum of $(\mathbf{I}\text{-}\mathbf{A}^*)^{-1}$. Similarly for GSD, where each element β_{ij} of the Gosh inverse $(\mathbf{I}\text{-}\mathbf{B})^{-1}$ is divided by the diagonal element in its row, β_{ii}, and GSD then equals the i^{th} row sum of $(\mathbf{I}\text{-}\mathbf{B}^*)^{-1}$.
For the derivation of the total linkage following the hypothetical extraction method (HEM) using the Leontief inverse, see Miller and Lahr (2001, pp. 411-4). The formula presented here follows from inverting a partitioned matrix, where **A** in the Leontief inverse $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is partitioned into (any) first sector i to be eliminated vs. all other sectors, and $\mathbf{A}_{ii} = \mathbf{A}_{ij} = \mathbf{A}_{ji} = 0$ in the scenario "$\mathbf{x}_j^R$."

Table 2. Correlation Coefficients Across 17 Sectors (Region Beijing-Tianjin, 1997)

	BL(1)	FL(1)	BL(2)	FL(2)	LSD	GSD	INT	TL
Output-linkage indicators								
BL(1)	1.000	*-0.448	***0.970	*0.432	0.199	***-0.724	***0.785	0.267
FL(1)		1.000	-0.373	-0.335	-0.411	***0.868	**-0.518	***-0.690
BL(2)			1.000	0.392	0.154	***-0.649	***0.689	0.212
FL(2)				1.000	-0.306	**-0.502	0.130	-0.125
LSD					1.000	-0.169	**0.582	***0.905
GSD						1.000	**-0.582	*-0.472
INT							1.000	**0.566
TL								1.000
Profit-linkage indicators								
BL(1)								
FL(1)		1.000	0.240	-0.196	0.343	**0.605	-0.300	-0.141
BL(2)			1.000	**0.557	***0.974	***0.892	***-0.607	-0.248
FL(2)				1.000	*0.416	0.304	-0.347	-0.346
LSD					1.000	***0.931	**-0.568	-0.146
GSD						1.000	***-0.678	-0.334
INT							1.000	***0.641
TL								1.000
Same type of linkage indicator, output- vs. profit-linkage								
		***0.827	***-0.806	***0.629	-0.047	***0.730	***0.925	***0.823

For the meaning of the individual column and row labels see Table 1.

BL(1) values in the case of profit-linkage coefficients are not meaningful; the (output) linkage coefficient is the share of intermediate purchases in inputs of sector j, with no possibility to transform this coefficient into a profit measure.

Significance levels: * 10%, ** 5%, *** 1%.

Source: manipulation of data from SIC (2005).

Table 3. Total Output-Linkage Coefficients, 17 Sectors, 8 Regions (1997)

	North-east	Beijing-Tianjin	North	East	South	Central	North-west	South-west
1. Agric.	0.500	0.465	0.424	0.477	0.344	0.389	0.270	0.286
2. Mining	0.417	0.117	0.169	0.314	0.272	0.156	0.185	0.418
3. Foods	+0.943	0.678	0.712	+0.799	0.745	+0.798	+0.736	0.693
4. Textiles	0.818	0.686	0.619	0.488	0.491	0.560	+0.660	+0.788
5. Wood	0.798	+0.923	+0.837	0.640	+0.769	0.581	0.558	0.665
6. Paper	0.749	0.602	0.652	0.647	0.748	0.535	0.509	0.593
7. Chemicals	0.595	0.312	0.324	0.291	0.387	0.348	0.505	0.556
8. Non-metals	0.769	+0.833	0.715	0.714	+0.813	0.624	0.564	+0.881
9. Metals	0.513	0.317	0.258	0.351	0.427	0.221	0.288	0.512
10. Machinery	+1.021	+0.946	0.485	+0.836	+0.794	+0.714	+0.615	+0.913
11. Transp. eq.	0.868	0.702	+0.966	+0.809	0.739	0.656	0.541	0.613
12. Electronic	+0.920	0.351	+0.851	0.725	0.618	+0.786	0.551	0.646
13. Other	0.893	0.633	0.662	0.773	0.555	0.400	0.394	0.760
14. Utilities	0.790	0.467	0.292	0.496	0.494	0.347	0.433	0.582
15. Construction	*1.517*	*1.291*	*1.406*	*1.361*	*1.112*	*1.407*	*0.953*	*1.246*
16. Commerce	0.684	0.596	0.415	0.530	0.542	0.364	0.362	0.482
17. Other serv.	*1.022*	0.362	0.461	0.568	0.512	0.502	0.396	0.449
Average	0.813	0.605	0.603	0.636	0.609	0.552	0.501	0.652
Coeff. of var.	0.304	0.463	0.494	0.389	0.338	0.506	0.360	0.333
Weighted Ave.^	0.747	0.520	0.524	0.609	0.552	0.508	0.424	0.528
Weighted C.V.^	0.389	0.529	0.536	0.417	0.378	0.551	0.483	0.493
Correlation coefficients: all signific. at the 0.1% level, except the North-Southwest value (1% level)								
Northeast	1.000	0.741	0.791	0.904	0.814	0.898	0.826	0.799
Beijing-T.		1.000	0.770	0.834	0.892	0.787	0.794	0.834
North			1.000	0.889	0.854	0.901	0.801	0.722
East				1.000	0.906	0.923	0.785	0.812
South					1.000	0.876	0.838	0.826
Central						1.000	0.909	0.806
Northwest							1.000	0.852
Southwest								1.000

The linkage indicator used is the TL (TOL) as defined in Table 1.

\+ Superscript + denotes the three sectors within industry (industry comprises sectors 2 through 14) with the highest linkage coefficient.

Italics mark those non-industrial sectors with a linkage coefficient at least as high as the third-highest linkage coefficient in industry.

^ Weights consist of sectoral value added. In the calculation of the standard deviation (used in the coefficient of variation), the squared deviation of a particular sector's linkage coefficient from the weighted average linkage coefficient was weighted with the sector's share in overall value added.

The complete labels of the individual sectors are: (1) 农业 (agriculture), (2) 采选业 (mining), (3) 食品制造及烟草加工业 (food processing and tobacco), (4) 纺织服装业 (textiles and apparel), (5) 木材加工及家具制造业 (wood processing and furniture manufacturing), (6) 造纸印刷及文教用品制造业 (paper manufacturing, printing, and cultural articles), (7) 化学工业 (chemicals), (8), 非金属矿物制品业 (processing of non-metal minerals), (9) 金属冶炼及制品业 (smelting and pressing of metals), (10) 机械工业 (machinery), (11) 交通运输设备制造业 (transport equipment), (12) 电气机械及电子通信设备制造业 (electric machinery and electronic communication equipment), (13) 其他制造业 (other manufacturing), (14)电力蒸气热水，煤气自来水生产供应业 (production and supply of electric power, steam, hot water, gas, and running water), (15) 建筑业 (construction), (16) 商业，运输业 (commerce and transportation), (17) 其他服务业 other services.

Source: manipulation of data from SIC (2005).

Table 4. Total Profit-Linkage Coefficients, 17 Sectors, 8 Regions (1997)

	North-east	Beijing-Tianjin	North	East	South	Central	North-west	South-west
1. Agric.	0.019	0.030	0.037	0.037	0.020	-0.005	0.017	0.015
2. Mining	0.010	0.009	0.012	0.025	0.016	$^{+}$-0.002	0.011	0.019
3. Foods	$^{+}$0.052	$^{+}$0.063	0.051	0.056	0.041	-0.035	$^{+}$0.072	0.020
4. Textiles	0.038	0.051	0.048	0.039	0.031	-0.015	$^{+}$0.063	$^{+}$0.032
5. Wood	$^{+}$0.047	$^{+}$0.057	$^{+}$0.067	0.048	$^{+}$0.046	-0.011	0.042	0.024
6. Paper	0.038	0.033	0.049	0.051	0.041	-0.008	0.043	0.026
7. Chemicals	0.047	0.028	0.021	0.022	0.024	-0.006	$^{+}$0.050	0.023
8. Non-metals	0.039	$^{+}$0.053	0.049	$^{+}$0.058	$^{+}$0.056	-0.008	0.042	$^{+}$0.036
9. Metals	0.030	0.024	0.018	0.030	0.030	$^{+}$-0.002	0.023	0.025
10. Machinery	0.035	0.043	0.033	$^{+}$0.058	$^{+}$0.046	-0.012	0.037	$^{+}$0.037
11. Transp. eq.	0.026	0.031	$^{+}$0.067	$^{+}$0.058	0.039	-0.013	0.025	0.024
12. Electronic	0.031	0.023	$^{+}$0.060	0.053	0.034	-0.014	0.033	0.025
13. Other	0.027	0.040	0.042	0.050	0.025	-0.010	0.024	0.029
14. Utilities	$^{+}$0.052	0.031	0.021	0.040	0.030	$^{+}$-0.006	0.038	0.021
15. Construct.	*0.062*	*0.069*	*0.094*	*0.094*	*0.050*	-0.021	*0.052*	*0.043*
16. Commerce	0.012	*0.061*	0.032	0.047	0.036	*-0.001*	0.019	*0.033*
17. Other serv.	*0.052*	0.014	0.033	0.037	0.028	-0.011	0.030	0.016
Average	0.036	0.039	0.043	0.047	0.035	-0.011	0.036	0.026
Coeff. of var.	0.395	0.442	0.475	0.341	0.303	-0.743	0.440	0.286
Weighted Ave.^	0.032	0.032	0.039	0.045	0.031	-0.009	0.030	0.022
Weighted C.V.^	0.543	0.627	0.485	0.372	0.307	-0.862	0.542	0.401
Weight. Ave.^^	0.018	0.025	0.041	0.044	0.031	-0.009	0.026	0.022
Weight. C.V.^^	0.833	0.713	0.516	0.379	0.274	-0.979	0.652	0.364
Correlation coefficients								
Northeast	1.000	0.335	0.411	0.390	*0.457	**-0.577	****0.755	0.167
Beijing-T.		1.000	**0.595	***0.658	***0.695	**-0.500	**0.562	***0.657
North			1.000	****0.851	***0.660	***-0.607	0.408	*0.470
East				1.000	****0.766	**-0.571	0.332	***0.680
South					1.000	*-0.421	*0.482	***0.677
Central						1.000	****-0.748	-0.136
Northwest							1.000	0.284
Southwest								1.000

The linkage indicator used is the total profit-linkage (TPL) indicator derived from the TL (TOL) in Table 1 as explained in the text.

The notes to Table 3, except on the significance of the correlation coefficients, apply in full to this table here.

Significance levels: * 10%, ** 5%, *** 1%, **** 0.1%.

^^ Weights consist of sectoral operating surplus. (Also see notes to previous table on "^.")

Source: manipulation of data from SIC (2005).

Table 5. Correlation Coefficients Across 13 Industrial Sectors, Total Linkage Vs. State Share

	Total output-linkage				Total profit-linkage			
	1994	1997	2000	2003	1994	1997	2000	2003
Beijing	*-0.481			-0.459	-0.415			*-0.505
Tianjin		**-0.644		-0.421		***-0.717		-0.268
Hebei	**-0.642	***-0.747	***-0.690	***-0.760	**-0.630	***-0.768	**-0.682	***-0.770
Shanxi	-0.016	-0.113	-0.124	0.024	-0.154	-0.082	0.072	0.020
Neimenggu			-0.335	*-0.526			-0.082	**-0.575
Liaoning		***-0.713	-0.337	**-0.591		-0.368	*-0.516	-0.384
Jilin	-0.248	-0.295			-0.288	*-0.507		
Heilongjiang	-0.027	-0.079	-0.450	-0.375	-0.143	-0.022	-0.290	-0.261
Shanghai	-0.170	-0.248	-0.085	0.022	-0.099	-0.193	-0.040	0.039
Jiangsu	-0.259	-0.303		-0.149	-0.265	-0.336		-0.148
Zhejiang	-0.165	-0.263	-0.251	-0.167	-0.148	-0.242	-0.230	-0.152
Anhui	-0.112	-0.277	-0.315	-0.444	-0.066	-0.021	0.079	0.192
Fujian	-0.285	*-0.492	-0.317	-0.228	-0.221	-0.429	-0.310	-0.252
Jiangxi		-0.464	**-0.636	-0.313		0.161	0.248	0.219
Shandong	***-0.697	***-0.694	***-0.697	***-0.694	***-0.701	**-0.689	***-0.702	***-0.701
Henan	*-0.475	*-0.476		-0.254	0.150	0.080		0.086
Hubei	-0.331	-0.291	-0.200	-0.242	0.026	0.042	0.080	0.179
Hunan		0.045	-0.102	-0.097		-0.235	-0.123	-0.119
Guangdong	-0.218	-0.243	-0.168	-0.017	-0.124	-0.176	-0.175	-0.044
Guangxi	-0.326	-0.380	-0.245	-0.412	-0.373	-0.408	-0.159	-0.342
Hainan	0.001				0.139			
Chongqing		-0.300	-0.400	-0.231		-0.353	-0.415	-0.335
Sichuan	-0.439	**-0.572	*-0.544	**-0.624	-0.375	*-0.475	**-0.521	**-0.647
Guizhou		-0.003	-0.177	-0.070		-0.143	-0.267	-0.236
Yunnan		-0.218	-0.431	-0.195		-0.379	**-0.635	-0.441
Tibet								
Shaanxi	-0.084	-0.025	-0.157	-0.139	-0.105	-0.094	-0.303	-0.309
Gansu								
Qinghai		*-0.508	-0.041	-0.401		**-0.559	-0.031	-0.333
Ningxia								
Xinjiang	-0.151	-0.161	0.334	-0.445	0.035	0.061	0.093	-0.124
Northeast	-0.244	**-0.569	-0.402	**-0.604	-0.179	-0.360	*-0.488	-0.308
Beijing-T.	*-0.481	**-0.644		-0.221	-0.415	***-0.717		-0.224
North	***-0.727	***-0.718	**-0.687	***-0.707	***-0.729	***-0.720	***-0.690	***-0.714
East	-0.240	-0.304	-0.031	-0.174	-0.241	-0.320	0.007	-0.164
South	-0.234	-0.330	-0.159	-0.036	-0.145	-0.265	-0.168	-0.062
Central	-0.344	-0.357	-0.135	-0.209	0.059	0.023	-0.048	-0.052
Northwest	-0.201	-0.219	-0.030	-0.397	-0.170	-0.209	-0.246	*-0.556
Southwest	-0.451	-0.405	-0.410	-0.414	-0.409	*-0.528	*-0.533	**-0.595

The 13 sectors covered are the 13 industrial sectors (sectors 2 through 14) out of the total of 17 sectors.

A province's linkage coefficients across the 13 industrial sectors are those of the region in which the province is located.

State share denotes the state's share in the output of all directly reporting industrial enterprises. Output is value added except in the case of Shanghai, Jiangxi, and Qinghai, where only gross output value added data are available for all years (for Jiangxi in 2000 and Qinghai in 2000 and 2003, value added data would be available but gross output value data are used for consistency). Hubei 2003 also uses gross output value data, because the sum sectoral SOSCE value added data significantly exceed the total for Hubei's SOSCEs (only for 2000 would gross output value data also have been available; in years other than 2003, value added is used). For each province, output data on the 40 individual sectors are aggregated to match the 13 industrial sector aggregation in the 1997 regional input-output table.

An empty cell means that no data are available on the output either of the directly reporting industrial enterprises, or of the state-owned enterprises, or of both.

The "state" means SOEs in 1994 and 1997, and typically SOSCEs in the other years (with a very few exceptions, where the provincial statistics come according to the old SOE definition).

Significance levels: * 10%, ** 5%, *** 1%.

For the regional coverage see note 17. Because linkage coefficients are regional values, combining these with (aggregated) regional state shares, done in the bottom part of the table, yields the most meaningful correlation coefficients.

Sources: total linkage indicators calculated from SIC (2005) (or see Table 3 and Table 4); output data from provincial statistical yearbooks of the relevant years, supplemented with sectoral output data on the directly reporting industrial enterprises from the *Industrial Yearbook* in 1994 for Hebei, Shanghai, and Xinjiang, and in 1997 for Shanghai and Qinghai.

Table 6. Explaining Provincial Growth

	I	II	III	IV	V	VI	VII	VIII	IX
Constant	****11.05	****12.58	****10.44	****4.76	****6.96	****5.69	****7.59	****4.62	****7.02
	(1.99)	(1.91)	(1.41)	(0.83)	(1.40)	(0.80)	(1.54)	(0.88)	(1.46)
Dummy 1994-97	****2.53	***5.19	***4.98	****3.00	****7.04	****3.11	****6.75	****3.30	****7.49
	(0.43)	(1.55)	(1.62)	(0.50)	(1.43)	(0.58)	(1.58)	(0.59)	(1.48)
Dummy 2000-03	****1.50	-1.18	-0.76	****1.61	-0.88	***1.51	-1.43	***1.66	-0.48
	(0.41)	(1.40)	(1.47)	(0.47)	(1.28)	(0.54)	(1.43)	(0.54)	(1.36)
Industrial sector variables									
TOL	-3.10	**-4.42							
	(2.33)	(2.03)							
Coeff. of var. of TOL	-1.55	-0.72							
	(4.37)	(3.81)							
TPL * dummy 1994-97				****112.7	**64.36			90.13	272.16
				(26.0)	(28.25)			(185.71)	(170.78)
TPL * dummy 1997-00				****146.7	****118.95			*252.04	187.44
				(25.7)	(27.10)			(150.04)	(136.15)
TPL * dummy 2000-03				****147.0	****126.64			***190.82	***168.09
				(25.6)	(28.91)			(64.54)	(58.26)
Coeff. of var. of TPL				-10.74	29.95			-16.84	20.28
				(26.33)	(24.43)			(30.59)	(28.47)
SOE share * dummy 1994-97		****-7.47	****-7.26		****-8.02		****-7.36		****-8.82
		(1.94)	(1.98)		(1.74)		(1.85)		(1.87)
SOE share * dummy 1997-00		**-3.52	**-3.65		*-2.52		-2.33		*-2.52
		(1.62)	(1.68)		(1.43)		(1.54)		(1.46)
SOE share * dummy 2000-03		0.67	0.10		1.07		2.04		0.59
		(1.57)	(1.62)		(1.31)		(1.54)		(1.51)
Coeff. of var. of SOE share		*6.80	4.85		-1.47		1.34		-2.62
		(3.76)	(3.72)		(3.22)		(3.42)		(3.40)
TPL-SOE * dummy 1994-97						***81.71	42.52	21.51	-207.49
						(27.20)	(28.49)	(181.13)	(164.92)
TPL-SOE * dummy 1997-00						****121.36	****97.08	-105.27	-64.20
						(27.04)	(27.62)	(147.78)	(129.00)
TPL-SOE * dummy 2000-03						****118.22	***100.67	-37.60	-36.03
						(26.90)	(29.71)	(63.38)	(62.35)

Central region dummy				****5.54	****4.54	****4.43	***3.38	****5.86	****4.79
				(1.06)	(1.13)	(1.08)	(1.13)	(1.17)	(1.27)
R-square	0.39	0.63	0.57	0.63	0.76	0.56	0.70	0.64	0.77
# of obs.	65	61	61	65	61	61	61	61	61

The unit of analysis is the province in one period. The dependent variable is provincial average annual real GDP growth in % (post-economic census values except in the case of Guizhou).

Significance levels: * 10%, ** 5%, *** 1%, **** 0.1%.

Residuals are normally distributed and homoscedastic (at the 5% significance level using the Jarque-Bera statistic and White's heteroscedasticity test), except in the second regression, where heteroscedasticity is indicated and was not corrected (robust standard errors in the second regression would be smaller for all coefficients). Ramsey RESET tests with three fitted values (2^{nd} to 4^{th} power) do not suggest misspecification of any of the regressions.

TOL: average sectoral total output linkage coefficient: region-specific sectoral linkage coefficients weighted by provincial first-year sectoral value added of the directly reporting industrial enterprises.

Coeff. of var.: coefficient of variation (with provincial first-year sectoral value added of the corresponding enterprise group as weight).

TPL: average sectoral total profit linkage coefficient: region-specific sectoral linkage coefficients weighted by provincial first-year sectoral value added of the directly reporting industrial enterprises.

SOE share: SOE share in value added of the directly reporting industrial enterprises; province-specific average across sectors, with provincial first-year sectoral value added of the directly reporting industrial enterprises as weights.

TPL-SOE: SOE average sectoral total profit linkage coefficient: region-specific sectoral linkage coefficients weighted by provincial first-year sectoral SOE value added (SOE value added in this sector divided by provincial SOE value added).

Central region: Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi. (A dummy variable is included in regressions that involve TPL due to the negative TPL coefficients of most sectors in the Central region.)

Number of observations: maximally 31 provinces in each of the three periods, except for the non-existence of Chongqing in 1994 (92 observations total). Hainan Province is omitted in the first period (see note 22).The regressions have fewer observations because sectoral value added data are not available for all provinces at all times; observations are available for the years 1994, 1997, 2000, and 2003 for the same provinces for which correlation coefficients are reported in Table 5, except for a few provinces as reported in the notes to that table where value added data is not available (needed here for consistency) and gross output value was used in Table 5.

Sources: Provincial real GDP growth: individual provincial statistical yearbooks of 2006 (incorporating the economic census revisions of 2004 except in the case of Guizhou); missing values are obtained from *Fifty-five Years*. Total linkage coefficient: Table 3 and Table 4 (for output and profit linkage). Province-specific sector-specific SOE share and sectoral share in provincial industrial value added: individual provincial statistical yearbooks.

Appendix A. Limitations to the interpretation of linkage coefficients and relevance to the analysis in this paper

Beyond Hirschman's caution towards the interpretation of quantitative measures of linkage coefficients, a number of authors, including Diamond (1976), McGilvray (1977), Hewings (1982), and Bulmer-Thomas (1982, section 12.5) raise further questions. First, in a less developed country some sectors, perhaps especially those for which high linkages are expected, may not yet exist. One solution would be to use the linkage coefficients of other—typically developed—countries for which they are available. But Bulmer-Thomas questions if the interdependence pattern found in less developed countries will eventually approximate that of more developed countries. Another solution would be to simply assume values for the missing input coefficients. The absence of precedents is less of a problem in the case of China in the reform period, because at the beginning of the reform period a basic industrial structure was already in place.

Second, an increase in gross output value is typically not a real world objective; an increase in income is. But this is not an argument for discarding linkage indicators altogether. One way to address the issue is to use income multipliers to turn output linkage indicators into income linkage indicators, or employment multipliers to turn output linkage indicators into employment measures. (For income, this is meaningful only if imports are non-competitive; if all imports are competitive, a one-unit change in final demand necessarily implies a one-unit change in income, value added, and the value of primary inputs).

The question of real world objectives is also a question of what weights, if any, to apply in the derivation of sectoral linkage coefficients. (For example, in the case of the second backward linkage indicator presented above, how to weight the Leontief inverse in the derivation of sectoral linkage coefficients?) If one wants to avoid the assumption of a uniform one-unit final demand change across all sectors, one can make each sector's final demand change proportional to the level of final demand in this sector. A further (or different) set of weights could be desirable depending on policy objectives. Thus, the Leontief inverse could be pre-multiplied by a diagonal policy matrix. However, policy objectives are likely to be multi-faceted and difficult to quantify.

In this paper, linkage indicators are turned into profit-linkage coefficients in order to match Hirschman's exposition and to capture the likely mechanism through which linkage effects operate in the economy. Whatever output change the government initiates, it is the impact on profit opportunities that triggers new investment and thereby economic growth.

Third, choosing sectors by linkage ranking ignores efficiency or comparative costs. For example, Riedel (1976) reports on sectors in Taiwan with low *domestic* linkage coefficients which grew rapidly while intermediate inputs were imported. But this observation does not contradict the linkage hypothesis in that (i) the linkage coefficient of a particular sector need not have any implications for the growth rate of that particular sector, and (ii) Riedel does not examine if import substitution occurs in the following years. This paper focuses on economy-wide growth; it also allows the linkage coefficients of one year to be related to economic growth several years later.

More generally, the input-output model assumes final demand to be exogenous. But a change in final demand will trigger changes in primary inputs, which include household income, and a change in household income will have an impact on final household demand. In order to endogenize final household demand and primary inputs, a more elaborate social accounting matrix framework is necessary. Given that the necessary data are not available for China, this is not an option. Compared to the direct and indirect effects captured in the input-output table framework, the induced effects via primary inputs are possibly minor. (If sectors are ranked by the value of linkage coefficients, the induced effects via primary inputs may affect the ranking. This happens if, for example, households' marginal expenditure patterns differ from households' average expenditure patterns. Such differences are likely, but if the induced effects are minor they may not change the ranking of sectors.)

Fourth, *ex ante* linkage analysis comes with a severe flaw: current linkage indices need not reflect future investment and growth opportunities that come into existence after new government investment that potentially changes linkage coefficients.[29] Linkage indices of more developed countries could be applied, but this assumes that the country under examination will go through an identical development process. *Ex post* linkage analysis appears more meaningful, but carries no implications for the choice of development strategies and government investment policies that reach into the future; at best, it can be used to evaluate government policies.[30] This paper provides an ex-post analysis to the extent that it examines the government's allocation of SOEs (after 1997) in response to linkage coefficients of different sectors and the ensuing effect on economy-wide growth.

Fifth, sectors with high backward linkages, by definition, depend heavily on intermediate goods, but these are often capital-intensive. The policy implications of favoring sectors with high backward linkages would be to support capital-intensive industries, but "this is not a position to which most LDCs [less developed countries] would want to be committed" (Bulmer-Thomas, 1982, p. 195). Hirschman (1984) addresses the issue implicitly when he argues that "once the indirect employment effects (via backward and forward linkages) are taken into account, investment in large-scale (capital-intensive) industry turns out to be just as employment-creating as investment in small-scale (labor-intensive) industry for the industrially advanced countries of Latin America" (p. 97). China's government appears to have no scruples about promoting capital-intensive industries, although some economic advisors (for example, Lin, 2003) promote a more labor-intensive "comparative advantage following" development strategy for China.[31]

Sixth, the level of aggregation matters in the identification of high-linkage sectors. The level of sectoral aggregation tends to be high, and inter-regional feedback mechanisms are typically ignored. In the case of China, there is nothing that can be done about the level of aggregation, given the data availability. However, a breakdown into 17 sectors is not trivial (given what the literature on other developing countries can offer). As to inter-regional feedback mechanisms, they may not be desirable (as explained in the section on linkage data above); China's regional data include intra-regional feedback effects in the provincial-level analysis.

Linkage indicators also come with technical limitations. Thus, input (or output) coefficients are unlikely to be constant over time, whether due to technological change, economies of scale, the invention of new products, substitution due to relative price changes, changes in consumer preferences for the products within one sector, or changes from domestically produced to imported inputs and vice-versa (for example, Miller and Blair, 1985, pp. 267f.). This concern is alleviated by Yotopoulos and Nugent's finding that the linkage coefficients for a number of sectors are not significantly different between developing and developed countries; i.e., even as China develops, changes in linkage coefficients are unlikely to be drastic, even over an extended period. A second technical constraint is potential limits to available primary inputs, whether that is labor or capital resources. Nevertheless, in a rapidly growing economy with widespread underemployment in agriculture and a government-controlled banking system, resources do not necessarily constitute an absolute constraint. If there is any scope for expansion, linkage coefficients may indicate how to make the most out of limited resources.

Appendix B. Industrial sector data and state ownership

The data on industrial sectors and state ownership come with several statistical breaks. First, the definition of SOEs changed in 1998 to include—in a new category of "state-owned and state-controlled enterprises" (SOSCEs)—those SOEs which, by becoming a shareholding company (possible since 1992/93), had escaped the pre-1998 definition of SOEs. Through 1997, "SOEs" comprise the traditional state-owned enterprises, state-owned joint operation enterprises (a very small category covering co-operations of two or more state-owned enterprises), and solely state-invested limited liability companies. Since 1998, what is published are often data on the aggregate of "state-owned and state-controlled enterprises" (SOSCEs) only. These comprise the "SOEs" defined as previously and, furthermore, all other shareholding companies (i.e., all other limited liability companies, plus all stock companies) in which the state has an absolute or relative controlling share. The Company Law was passed in 1992 and enterprises only gradually switched to the company system, which puts some limitation on the statistical break between the SOE and SOSCE series in 1997-98.

In 1997, SOEs had value added of 919.293b yuan RMB. In 1998, SOSCEs had value added of 1107.690b yuan RMB. I.e., value added of the state category (SOEs in 1997, SOSCEs in 1998) grew by 20.5%. In comparison, industry-wide value added grew by 3.1% (8.9% in real terms). The state share in the value added of the directly reporting industrial enterprises in 1997 was 46.3% and the SOSCE share in 1998 57.0%. (*Statistical Yearbook 1998*, p. 444; *1999*, pp. 55, 57, 432)

The source of provincial industrial data by sector used here are the provincial statistical yearbooks (the only publicly available source). Not all provinces immediately switched to the new classification scheme in 1998. Even by 2000, half a dozen provinces still adhered to the labels "SOEs" and "industrial enterprises with independent accounting systems at township level and above" (see below). It could be that they still followed the old classification scheme, or that they simply had not bothered to revise the terminology in their publications.

Second, the available data by industrial sector do not cover all industrial production units. They only cover the "directly reporting industrial enterprises" (those that report regularly and directly to China's statistical authority). The definition of directly reporting industrial enterprises changed in 1998.

Up through 1997, the directly reporting industrial enterprises comprise all enterprises with independent accounting systems at township level and above (which include all SOEs), and since 1998 (though more gradually phased in at the provincial level) all state-owned and state-controlled enterprises plus all non-state enterprises with independent accounting systems and annual sales revenue in excess of 5m yuan RMB. The statistical break in the overall coverage of the directly reporting industrial enterprises is on the order of a few percentage points: at the national level, in 1997, the directly reporting industrial enterprises accounted for 62.5% of industrial value added, and in 1998 (following the new definition), for 58.1%. The years 1997/1998 are a low point for the share of directly reporting industrial enterprises in industrial value added. In 1994, the share was 80.1%. By 2007, the share had climbed from its all-time 1998 low of 58.1% to 105.9%. A value above 100% is logically impossible. (*Statistical Yearbook 1995*, pp. 32, 388; *1998*, pp. 55, 444; *1999*, pp. 55, 433; *2009*, pp. 37, 494. For a discussion of this trend see Holz, 2008.)

A comparison of the sectoral data on the directly reporting industrial enterprises with the industrial and economic census data of 1995 and 2004—both censuses covering a slightly larger but still incomplete aggregate—shows that the production units not covered in the data on directly reporting industrial enterprises are concentrated in sectors which, in the data on directly reporting industrial enterprises, come with a low degree of state ownership (Holz, 2006). In other words, if in a particular industrial sector the share of SOEs in the output of all directly reporting industrial enterprises is low, then it is likely to be even lower (and possibly substantially lower) in the (unknown) output of all production units in this industrial sector. On the other hand, if in a particular industrial sector the share of SOEs in the output of all directly reporting industrial enterprises is high, then it is likely to be the same or only minimally lower in the (unknown) output of all production units in this industrial sector. Thus, in terms of the share of state ownership in sectoral value added, the true share is likely to follow a more pronounced pattern than the one found in the available data on the directly reporting industrial enterprises.

Third, the sectoral classification scheme was revised in 2003, but at the level of aggregation used in the regional input-output table the changes appear minor. The 40 industrial sectors of the earlier sectoral classification scheme can be seamlessly aggregated into the 13 *industrial* sectors used in the 1997 multi-regional input-output table (following some explanations in the source, SIC, 2005), and the 39 industrial sectors of the current sectoral classification scheme can be matched well.

Fourth, beyond the period covered in the analysis here, the 2004 economic census unearthed a number of enterprises with annual sales revenue in excess of 5m yuan RMB that had previously managed to escape the reporting requirement. Industrial value added of 2004 was revised up by 3.8% (*Statistical Yearbook 2005*, p. 51; *2006*, p. 57). For the directly reporting industrial enterprises and their sub-category of SOEs no revised 2004 data or revised data for earlier years were published. If SOEs and non-SOEs among the directly reporting industrial enterprises are equally affected by the revisions, then this statistical break does not affect the share of SOEs in the directly reporting industrial enterprises in 2004 or earlier years, and therefore has no implications for the analysis here. But they may also be unequally affected because SOEs are supposedly all captured in the official statistics independent of their sales revenue. Nevertheless, the size of the overall revision to industrial value added at 3.8% could be small enough to ignore this statistical break. The group of directly reporting industrial enterprises by nature changes every year as enterprises newly enter or exit this pool. In the year 2004, the entry was probably slightly larger than in other years due to the special census efforts to capture all relevant enterprises (with no possibility to revise the data of earlier years).

Notes

[1] An earlier literature compares the production structures of different countries using input-output tables (for example, Chenery and Watanabe, 1958) without exploring the unbalanced growth hypothesis

[2] Further, Wade (2009, pp. 352ff.) views industrial policy as "any sectorally or activity-targeted interventions" and distinguishes between government leadership of the market (leading decentralized private producers to do something they would otherwise not do) and government followership of the market (betting on some of what the private sector is already doing); the unbalanced growth hypothesis suggests government leadership, including in form of government-organized production. Pack and Saggi (2006, pp. 267f.) define industrial policy as "any type of selective government intervention or policy that attempts to alter the structure of production in favor of sectors that are expected to offer better prospects for economic growth in a way that would not occur in the absence of such intervention in the market equilibrium." This definition, too, includes the unbalanced growth hypothesis.

[3] For sector-specific industrial policy studies in the case of China (electronics manufacturing, aircraft manufacturing, and steel) see Zhao et al. (2007), Goldstein (2006), and Sun (2005).

[4] For an overview of the ownership transition see Naughton (1996; 2007, Chapter 13).

[5] Recent quantitative analyses of privatization appear to not control for such factors as the government-financed reductions in social burdens, the debt write-offs, and the restructuring that inevitably accompany privatization. I.e., the performance of newly privatized firms may improve due to reasons other than privatization. While much of the discussion of SOEs has focused on profitability, there is also a literature on efficiency; it typically concludes on the inferiority of SOEs (see, for ex., Jefferson et al., 2000).

[6] A discussion of Yotoupolos and Nugent's (1973) paper in a later issue of the *Quarterly Journal of Economics* by Laumas (1976), Boucher (1976), Riedel (1976), and Jones (1976) provides a number of arguments which Yotoupolos and Nugent (1976) defend themselves against. Thus, sectors are weighted in their original analysis, imports are excluded in the calculation of their linkage coefficients, other linkage indicators are highly correlated with theirs, and the level of aggregation was dictated by the data.

[7] There is likely also a discrepancy in how linkage effects and growth rates are measured. The linkage index measures the impact of one unit change in final demand of one particular sector on *gross output value* across the economy. Growth rates are presumably measured in terms of *value added*. (The authors do not clarify.)

[8] The division in that formula by the number of sectors (to average across sectors) in their equation appears redundant given that the weights (applied to the squared sectoral deviations from the linkage-weighted economy-wide growth rate) consist of the *share* of each sector in GDP.

[9] An earlier article by Yotopoulos and Lau (1970) examines the relationship of imbalance and growth without reference to linkages; it concludes in favor of balanced growth. (The authors defend their measure of imbalance in 1975.)

[10] These include Bhalla and Ma (1990) with a comparison of China's 1981 linkage coefficients to those in other countries and a focus on agricultural vs. rural non-farm vs. light industry vs. heavy industry linkages, Heimler (1991) with sectoral indices of vertical integration for 1981, Li and Xue (1998) with sectoral linkage coefficients for 1981, 1983, 1987, 1990, 1992, and 1995 (using constant-price input-output tables), Liu (2003) with sectoral linkage coefficients for 1997, and Andreosso-O'Callaghan and Yue (2004) with an examination of the development of a range of sectoral linkage coefficients between 1987 and 1997. Input-output literature for China that does not focus on linkage effects includes an examination of structural change over time (Coady and Jie, 1993, for 1981, 1983 and 1987 using a proportional column filter and Andreosso-O'Callaghan and Yue, 2004, for 1987 and 1995 using a biproportional filter) and a decomposition of output growth into changes of final demand level, final demand structure, technical coefficients, and exports (Andreosso-O'Callaghan and Yue, 2002). Ichimura and Wang (2003) examine China's interregional dependence based on 7 regions and 9 sectors. Xu and Liu (2004) contain a large collection of short articles related to input-output analysis. Li (1992) is a textbook on input-output table techniques. Polenske and Chen (1991) present a historical overview over input-output tables in China as well as numerous applications that provide evidence of extensive applied input-output work in China.

[11] This may be clearer if the Leontief inverse is rewritten as $(I-A)^{-1} = (I + A + A^2 + A^3 + \ldots)$; writing out A^2, A^3 etc. reveals the forward linkage input coefficients. Backward and forward linkage indicators both share the intra-sectoral flows, i.e., the intra-sectoral flows are double-counted. Diamond (1976) suggests two possible adjustments to the Leontief inverse, namely to subtract out the initial one-unit increase in the final demand for the particular sector under consideration, and to further omit the intra-industry effects in this sector. The first adjustment should not affect the ranking of sectors by linkage coefficient because each sector under consideration contains the initial one-unit increase in final demand.

[12] Cai and Leung's work builds on a long line of literature on the extraction method, originating with Strassert (1968) and Schultz (1977). Cella (1984) then decomposes the total linkage coefficient into backward and forward linkages (with backward linkages, however, including some forward elements, and vice versa). Among the subsequent literature, Clements (1990) provides an adjustment to Cella's split of the total linkage indicator into

backward and forward linkage, which also implies a different normalization. Sonis et al. (1995) introduce the concept of pure linkages that further disentangles the backward and forward linkages (Cai and Leung interpret Sonis' pure linkages and suggest their alternatives). Dietzenbacher and Linden (1997) propose an approach that allows for a natural distinction of the interdependencies into backward and forward linkages.

[13] A number of other total linkage indicators are possible and presented by Miller and Lahr (2001). Cella (1984) includes the output effect in the omitted sector in his total linkage effect; the part of his formula that covers the non-extracted sector is identical to the formula used here. While government activity in one sector may trigger non-government activity in the same sector, the two cannot be distinguished. Therefore, it seems more appropriate to examine the impact of the extracted sector on the non-extracted sectors.

[14] See, for example, Jones (1976, p. 329). For the linkage coefficients calculated from the columns of the Leontief inverse or Gosh inverse, Jones shows that the sum of sectoral BL(2)s weighted by the (sectoral) value of output equals the sum of sectoral FL(2)s weighted by the (sectoral) value of output; i.e., the output-weighted sum of sectoral BL(2)s *or* FL(2)s equally yields the coefficient of interdependence. In order to determine a *relative degree* of sectoral linkage, one option is to standardize by the average degree of linkage across the economy (linkage coefficient of a particular sector divided by average linkage coefficient across all sectors). Another option, if data on several geographic entities with identical sectoral classification are available, is to standardize by the average degree of linkage in the particular sector across geographic entities. Standardization is not needed below.

[15] For a discussion of the term "operating surplus" in the National Income and Product Accounts vs. the accounting term " profit," in the case of China's industry, see Holz (2003).

[16] Naughton (2003) believes that provincial input-output tables should exist, in accordance with the 5-year frequency, for 1982, 1987, 1992, 1997, and 2002. A national input-output table was possibly compiled also for 1973.

[17] The eight regions are Northeast (Heilongjiang, Jilin, Liaoning), Beijing-Tianjin, North (Hebei, Shandong), East (Jiangsu, Shanghai, Zhejiang), South (Fujian, Guangdong, Hainan), Central (Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi), Northwest (Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjian), and Southwest (Sichuan, Chongqing, Guangxi, Yunnan, Guizhou, Tibet). The 17 sectors are listed in Table 3. The sectors in the 1987 inter-regional input-output table (not used here) are agriculture, mining and processing, light industry, energy industry, heavy industry and chemical industry, construction, transportation & post & telecommunications, commerce and catering, and "non-material" sectors (Ichimura and Wang, 2003, p. 14).

[18] Because domestic trade flows are not particularly large, the necessary choice between local vs. national planning is unlikely to be important. Across the eight regions in 1997, for intermediate use between 8-13% of GOV was domestically imported, while between 6-14% of final demand was. (These numbers, 8% etc., reflect an individual region's aggregate across sectors; the percentages differ further for each sector in a region.) On the domestic export side, between 8-21% of domestic gross output value of a region's intermediate sales went to other regions, and between 3-11 % of final demand. (Again, 8% etc. reflect a region's aggregate value.)

[19] The central government, under the State-owned Asset Supervision and Administration Commission, retains only a few large holding companies (196 in 2003, merged to 116 in 2009). For the transfer of centrally owned coal mines to provinces in 1998 see, for example, Su (2004). Regarding investment, local investment (independent of ownership form) in 1997 was more than twice the size of central investment, and in 2008 eight times (*Statistical Yearbook 2009*, p. 181). For some years, SOE-specific data are available; in 1997, local SOE investment was 1.5 times central SOE investment (*Investment Yearbook 1998*, p. 52). Whatever investment occurs in centrally owned SOEs is furthermore likely to be at least partially influenced by local government policy.

[20] International imports could be made non-competitive by assuming each sector's international imports to occur in some specific proportion across sectors (and non-import final demand) to which they are directed; but it is doubtful if such proportionality assumptions are plausible. International imports accounted for the following percentages of regional final demand (where final demand includes international imports): 9 (Northeast), 36 (Beijing-Tianjin), 7 (North), 20 (East), 31 (South), 3 (Central), 5 (Northwest), 2 (Southwest).

[21] In the case of the INT and GSD, the Central region's sectoral pattern of profit linkage coefficients is *positively* correlated with those in other regions.

[22] Throughout all regressions reported in this section, Hainan Province is omitted in the first period (1994-97). If included, its residual constitutes a far outlier that can significantly influence the regression coefficients. The outlier status originates in an unusually low provincial real growth rate of value added with an average annual 5.1% in the first period. These values contrast with 41%, 21%, and 11% annual real growth rates in 1992 through 1994.

[23] A coefficient of variation of TPL-SOE is not included because its interpretation appears not straightforward. If included, its coefficient tends to be insignificant except in the third period, when it tends to be negative and significant. (This is independent of if the squared term in the standard deviation is weighted by the SOE share or not.) Inclusion of the coefficient of variation has only a very minor impact on the coefficients of the other variables.

[24] One might want to argue that a particular degree of imbalance in the state share, matching in some way the sectoral distribution of linkage values, is optimal for economic growth. But including the coefficient of variation of the state share in linear *and* squared form in the regressions also yields insignificant coefficients.

[25] In these regressions, all 92 observations (31 provinces, of which Chongqing only came into existence in the second period), less Hainan Province in the first period, can be used, whereas the regressions reported in Table 6 are restricted to those combinations of provinces and time periods for which industrial SOE (or directly reporting industrial enterprise) value added data are available. TOL and TPL involve sectoral weights (that, at the provincial level, require the use of value added data for the directly reporting industrial enterprises); similarly, in the calculation of the standard deviation (used in the derivation of the coefficient of variation of TOL or TPL) the squared deviations from the mean are weighted by sectoral value added. Not applying sectoral value added weights when aggregating sectoral TL coefficients to an economy-wide regional TL value makes no qualitative difference to the results.

[26] The necessary deflators are national sectoral deflators derived from nominal and real gross output values in the 37-40 industrial sectors, except in 2003 when, lacking real gross output value data, the ex-factory price index is used. (The NBS's procedure for deriving the industrial real growth rate of value added closely matches the procedure chosen here; see Holz, 2006.) Data sources are the annual *Industrial Statistical Yearbook* and the annual *Statistical Yearbook* series.

[27] Experimenting with the inclusion of a variable measuring capital growth (based on the original value of fixed assets deflated in full at the current year's investment prices), the variable tends to be insignificant or barely significant (with a positive sign).

[28] See http://www.ndrc.gov.cn/fzgh/ghwb/gjjh/P020070912638573307712.pdf, accessed April 2010.

[29] A counter-example is the potential for import substitution revealed by the difference between an intermediate input coefficient matrix that incorporates vs. excludes imports.

[30] Bulmer-Thomas (1982, p. 196) sees a role for *ex post* linkage analysis to (i) check if government policy, at a given point in time, is consistent with the ranking of sectors, (ii) identify 'enclave' sectors (which could trigger policies to integrate these into the national economy), (iii) track changes in the sectoral interdependence of a country over time, and (iv) make international comparisons at a given point in time.

[31] A high degree of labor intensity necessarily implies low linkage coefficients. Social accounting matrices, in contrast to input-output tables, would take into account the use of the relatively large newly created income of laborers when investment occurs in high labor-intensity low-linkage sectors.