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From Licence Raj to Market Forces: The Determinants of Industrial Structure in India after Reform

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This paper explores the relationship between factor endowments, technology and industrial structure, using a panel data-set of Indian industries across states, industries and time. Factor endowments and technology are found to be significantly related to industry shares, and this is robust to controlling for the slow adjustment of industrial structure. I also consider the impact of the liberalization of the Indian economy beginning in 1985 and 1991 on the relationship between these variables. While industrial structure is always positively related to technological advantage, factor endowments play an increasingly significant role after liberalization.

Introduction

The Indian economy has been in transition since the early 1980s. At the start of the 1980s the economy was largely based on central planning, leaving private enterprise on the periphery of the economy, governed by a strict set of licensing requirements. This started to change in the 1980s and 1990s. First Indira Gandhi in 1980 and then Rajiv Gandhi in 1985 began a process of liberalizing the economy. As discussed further in Section I, this was followed in 1991 by a much larger-scale liberalization, which involved removing almost all licensing requirements from industry. Kohli (2006a, b) charts the performance of the economy since liberalization, and discusses the politics behind the policy change.

In this paper I focus on manufacturing industry. The Industrial Policy Resolution of 1956 emphasized the role of heavy industry as the driving force for economic growth. The resolution also made the state the main player in developing manufacturing industries. As a result, the liberalization of the 1980s and 1990s had a large impact on manufacturing. I investigate the relationship between factor endowments, technology and industrial structure in India, using a panel across industries and states, between 1980 and 1997. This relationship follows directly from the neoclassical model of trade and production in general equilibrium. However, the neoclassical model assumes a market economy free from government intervention, which is not the case in India in the time period under study. Therefore the question I ask is: to what extent does the prediction of the neoclassical model hold, in an economy that is heavily influenced by government policy?[1]

I also extend the basic framework to investigate whether the liberalization of the Indian economy in 1985 and 1991 has changed the relationship between industrial structure, factor endowments and technology. This involves testing for the presence of structural breaks in the econometric specification, and exploring the relationship between the three variables in each sub-period. By doing so, I can examine whether a centrally planned economy in the early 1980s related industry share to factor endowments and technology in the same way as the more market-orientated economy of the 1990s.

My basic approach is that of Harrigan (1997) in his study of the neoclassical model for a panel of OECD countries. This approach is based on a translog revenue function, from which is derived the estimated equation that relates industry share to technology, factor endowments, and a set of state and time fixed effects. A modification of this approach which avoids measurement of TFP for the measure of technology, has been used in Harrigan and Zakrajsek (2000) in a follow-up study on a larger sample of both OECD and non-OECD countries, and by Redding and Vera-Martin (2006) in their study of industrial structure in EU regions.

In this paper, I adopt the original approach used by Harrigan (1997), using a new panel of cross-state industry data on India between 1980 and 1997 to estimate the relationship between factor endowments, technological differences and industrial structure. Provided the assumptions of the neoclassical model hold, the relationship between these three sets of variables should hold both across and within countries.[2] The main innovation with respect to the previous literature is my investigation of the possibility of structural breaks in the relationship between factor endowments, technologies and industrial structure as a result of the policy reforms of 1985 and 1991.

The literature on the liberalization of the Indian economy is immense. Recent surveys of the progress and performance of the liberalization programmes include Srinivasan (2003) and Panagariya (2004). The general consensus seems to be that, while the reform process has increased the real growth rate of the Indian economy (from an average of 3.5% between 1950 and 1980, to 5.7% in the 1980s, to an average of 6.2% in the 1990s), it is still unfinished, and much more needs to be done, especially with regard to some sectors such as infrastructure, labour laws, health and education, which so far have not been the main focus of the reforms.[3] Section I gives a more detailed description of the reform process, especially as it relates to industrial activity.

Briefly, my results are as follows. First, my estimate of total factor productivity (TFP) provides evidence of technological improvement in the sample period. However, this improvement is not uniform across industries, as some industries showed rapid TFP growth while others showed no evidence of technological improvement. Second, both factor endowments and technology are strongly associated with the share of an industry in the gross domestic product of a state. Factor endowments are much more significantly related to industry share in heavy industries than in textiles and other light manufacturing. Third, superior technology in an industry is associated with larger shares of that industry. Fourth, there is strong evidence that both rounds of liberalization of the economy, i.e. beginning in 1985 and in 1991, are associated with structural breaks in the relationship between factor endowments, technology and industrial structure. In particular, the relationship between factor endowments and industrial structure is strengthened by the liberalization process. All of these results suggest that the economic forces underlying the neoclassical model play an important role in determining the industrial structure of India, and that the shift from a primarily centrally planned economy to one emphasizing market forces has led to a change in the relationship between technology, factor endowments and industrial structure.

The rest of this paper is structured as follows. The next section outlines the empirical environment, providing a description of the data and the industrial policy of India. This is followed in Section II by the empirical model used. Section III details the results, and Section IV concludes.

I. Empirical Environment

This section first outlines the institutional environment in which the empirical exercise was carried out, then describes the data used.

Industrial policy and economic performance in India

The data used for this empirical study spans the period 1980–97, covering both sides of the economic reform that was begun hesitantly in India in the early 1980s and more broadly in 1991. Industrial licensing was a central part of industrial policy in India prior to reform. The Industries (Development and Regulation) Act of 1951 imposed a licensing requirement on private industry in almost all industries. A licence was required to set up a new unit, expand capacity by more than 25%, or manufacture a new product.

Prior to the major reform of 1991, industrial policy was governed by the Industrial Policy Resolution of 1956. All industries were divided into three categories: those that were to be the exclusive responsibility of the state, those that were to be progressively state-owned, and those left to private enterprise. Included in the first two categories was virtually every heavy industry. The resolution aims to reduce regional disparities in industrial performance; however, it recognizes that existing concentrations of industrial activity are often determined by factor endowments and infrastructure. Hence it also seeks to develop such facilities in underdeveloped regions. All in all, the tone of the 1956 Resolution is one of state dominance in industry, with the private sector relegated to secondary importance.

In 1985 and 1986, Rajiv Gandhi's government initiated a set of policies to liberalize the Indian economy. Industrial licensing was abolished for 25 broad industry groups. Licensing requirements for capacity expansion and product diversification were relaxed. Import tariffs were also reduced.

In 1991 India began further liberalization of its economy. This liberalization was initiated by the incoming government as a result of a balance of payments crisis in 1991, which in turn was caused by fiscal imbalances throughout the 1980s. Because the reform was caused by a crisis, initial reforms were focused on macroeconomic stabilization. Simultaneously, reform was begun in industrial policy, trade and exchange rate policies, foreign investment policy, taxes, the financial sector and the public sector. These measures were much more comprehensive than those implemented by Rajiv Gandhi in 1985.

The tone of the Statement of Industrial Policy 1991, coinciding with the reform of the economy in 1991, is substantially different from that of the 1956 Resolution. It recognizes that public sector enterprises tend to be inefficient and unproductive, and calls for a reduction in the number of industries reserved for the public sector to those related to the military, fuels, mining and railroads, and also for the abolition of industrial licensing for almost all other industries. The limit on investments in large Indian and foreign companies was scrapped for many high-priority, advanced technology industries, and access to foreign technology was made much easier. Overall, it is a statement of industrial liberalization.

The reform from a state-led economic system to a more free-market system has implications for the empirical strategy to be detailed in Section II. This empirical strategy assumes free, competitive markets. The question is whether the centrally planned economy of the early 1980s behaved differently, in terms of the relationship between technology, factor endowments and industrial structure, from the market-driven economy of the 1990s. Therefore one of my empirical strategies is to interact post-reform dummies with factor endowments and technology, to allow me to identify any changes in the relationship between my variables of interest.

Data

My main data-set comes from the Annual Survey of Industries (ASI) produced by the Central Statistical Organization of India. The ASI is a survey of registered manufacturing firms, i.e. firms having either 20 or more workers without electrical power, or 10 or more workers with electrical power.[4] This annual publication consists of data at the 3-digit level by state, which I aggregated up to the 2-digit level, since factor endowment differences may be more important in determining the mix of broad industry aggregates. I further combined industries 24 and 25 into a single industry for the manufacture of all textiles other than cotton; this was because industry 25 (manufacture of jute and other vegetable textiles) appears in only a few states, so that the few TFP observations for that industry would prove problematic when running regressions including TFP as an independent variable. I therefore had a total of 18 industries. Table 1 shows the National Industrial Classification at the 2-digit level. Notice that we can divide industries into light industries (industries 20–29) and heavy industries (industries 30–37). This gives a useful shorthand for summarizing my results.

There was a total of 25 states and 7 union territories in the sample period. The analysis was performed on the 16 largest states in terms of industrial output because of data limitations; these states represent over 97% of the total population of India. For each industry–state pair, data on a wide range of variables are available, from number of factories to capital employed, workers employed, total inputs and output, value added, and capital formation. Data are for the period 1980–97, which is an especially interesting period because of the liberalization of the Indian economy.

Data on endowments come from a variety of sources; the Data Appendix provides further details on sources and the construction of data. A key source is the data-set compiled by Ozler *et al.* (1996), augmented by Besley and Burgess (2000, 2004), which I further extended using data from the Statistical Abstract of India (various years); see Besley and Burgess (2000, 2004) for further details on the data.

Factor endowments

Table 2 provides summary statistics of factor endowments. I used three measures of factor endowments: capital stock, population, and crop area. The capital variable is real fixed capital. Capital accumulation in India has been extremely rapid over the sample period, apart from Bihar where the capital–labour ratio actually decreased between 1980 and 1997. On average, each state had almost four times as much real fixed capital per capita in 1997 as it did in 1980, with Gujarat posting the largest increase of almost seven times the 1980 real per capita capital stock.

Population and population growth rates also vary significantly across states. The most populous state, Uttar Pradesh, had close to 156 million people in 1997, while the smallest states in terms of population were Jammu and Kashmir, and Haryana, with 8.9 million and 18.9 million people, respectively. I have omitted the smallest states and union territories from the sample. In terms of growth rates, there are states with relatively low growth rates (Tamil Nadu and Kerala, where the population grew by 23.5% and 25.6%, respectively, between 1980 and 1997), and states with high growth rates, such as Jammu and Kashmir and Rajasthan, where the increase in population over the sample period was 50.2% and 48.9% respectively. With the increasing population and the much slower increase (and occasional declines) in the area under crops, cropped area per capita is declining in every state in India.

In our empirical work, we use these factor endowments as exogenous variables that explain the share of an industry in a state. However, if factors of production are mobile across locations, it is also possible that these endowments are endogenously determined;

TABLE 1
INDIA NATIONAL INDUSTRIAL CLASSIFICATION (2-DIGIT LEVEL)

20	Food products
21	Food products
22	Beverages, tobacco and related products
23	Cotton textiles
24	Wool, silk and man-made fibre textiles
25	Jute and other vegetable fibre textiles (except cotton and coir)
26	Textile products (including wearing apparel)
27	Wood and wood products; furniture and fixtures
28	Paper and paper products and printing, publishing and allied industries
29	Leather and products of leather, fur and substitutes of leather
30	Basic chemicals and chemical products
31	Rubber, plastic, petroleum and coal products; processing of nuclear fuels
32	Non-metallic mineral products
33	Basic metal and alloys industries
34	Metal products and parts, except machinery and equipment
35	Machinery and equipment other than transport equipment
36	Machinery and equipment other than transport equipment
37	Transport equipment and parts
38	Other manufacturing industries

that is, changes in production structure can lead to changes in factor endowments. This issue is discussed in the following section.

Share of industries

Table 2 presents data on the share of registered manufacturing in each state in State Domestic Product (SDP) for 1980, 1991 and 1997, while Figure 1 presents the time series of this share (each state rescaled to show changes over time more clearly). What is clear from both table and figure is the difference across states in terms of share of registered manufacturing in SDP: this ranges from approximately 2% in Jammu and Kashmir to over 15% in Gujarat, Maharashtra and Tamil Nadu.

There are also changes in this share over time. Despite the rapid growth of the Indian economy over the sample period, the share of registered manufacturing has not increased very much. Only four states posted large increases in the registered manufacturing share of SDP: Andhra Pradesh, Gujarat, Haryana and Punjab. West Bengal exhibited a falling share of SDP for registered manufacturing. In general, state industry share tends to follow the same trend before and after the reform; notable exceptions are Gujarat and Haryana, where industry share increased dramatically post-reform, and Karnataka, where industry had been increasing as a share of SDP before reform, but decreased afterwards.

Turning to industry-level data for registered manufacturing, the share of 2-digit industries in total registered manufacturing also varies considerably across states and over time. Consider, for example, industry 20 (food products). In 1980 the share of this industry in total industrial value added varied across states from less than 2% in Madhya Pradesh, Maharashtra, Rajasthan and West Bengal to over 10% in Andhra Pradesh, Jammu and Kashmir, Punjab and Uttar Pradesh. Similar patterns can be found in

TABLE 2
DESCRIPTIVE STATISTICS

	Real fixed capital (million rupees)*		Real per capita fixed capital		Area under crops ('000 hectares)		Per capita cropped area	
State	1980	1997	1980	1997	1980	1997	1980	1997
Andhra Pradesh	8675	60000	163.4	807.1	12281	13777	0.231	0.185
Assam	795	3561	44.4	138.4	3446	3979	0.193	0.155
Bihar	26900	35100	388.7	353.5	11148	10262	0.161	0.103
Gujarat	17000	175000	502.2	3774.6	10695	11064	0.317	0.239
Haryana	4441	25300	347.2	1342.1	5462	6174	0.427	0.327
Jammu & Kashmir	34	110	5.7	12.6	974	1081	0.165	0.121
Karnataka	8781	42800	238.9	863.6	10660	12712	0.290	0.257
Kerala	4330	10600	170.8	331.9	2862	2974	0.113	0.093
Madhya Pradesh	13700	43300	264.7	575.4	21402	25862	0.414	0.344
Maharashtra	27500	183000	441.3	2044.9	20270	22117	0.326	0.247
Orissa	4249	7751	162.1	217.6	8746	6764	0.334	0.190
Punjab	5682	19000	341.5	829.0	6763	7932	0.407	0.345
Rajasthan	4053	33500	120.0	666.4	17350	21714	0.514	0.432
Tamil Nadu	12600	74000	260.9	1243.3	6469	6646	0.134	0.112
Uttar Pradesh	8805	76900	80.3	494.1	24574	26465	0.224	0.170
West Bengal	13000	42100	240.3	554.9	7620	9145	0.141	0.121

	Real per capita net SDP (rupees)		Population ('000)		Share of registered manufacturing in SDP**		
State	1980	1997	1980	1997	1980	1991	1997
Andhra Pradesh	1474	3446	53077	74324	5.85	9.57	9.49
Assam	1380	2127	17893	25721	4.16	7.44	4.84
Bihar	985	1445	69242	99309	3.45	9.15	7.19
Gujarat	2074	5291	33754	46358	15.11	14.10	26.04
Haryana	2534	5739	12793	18878	10.05	10.53	16.27
Jammu & Kashmir	1928	2465	5910	8907	1.34	1.70	2.70
Karnataka	1624	3805	36750	49560	9.06	10.48	9.43
Kerala	1621	3873	25357	31839	7.59	8.22	7.64
Madhya Pradesh	1463	2514	51655	75200	6.86	6.16	10.64
Maharashtra	2603	5979	62263	89612	19.13	17.73	17.22
Orissa	1420	2085	26210	35619	4.74	7.25	5.34
Punjab	2859	6349	16638	22969	5.91	7.82	8.86
Rajasthan	1313	3036	33771	50293	4.83	6.53	5.23
Tamil Nadu	1601	4229	48184	59513	14.95	16.42	14.56
Uttar Pradesh	1366	2365	109677	155723	4.34	7.87	7.54
West Bengal	1894	3460	54100	75864	12.16	7.10	6.50

*Base year 1981. Figures for capital stock in West Bengal in 1997 are actually for 1996 as data for 1997 are unavailable.
**The value for Jammu and Kashmir for 1997 is the 1996 value.

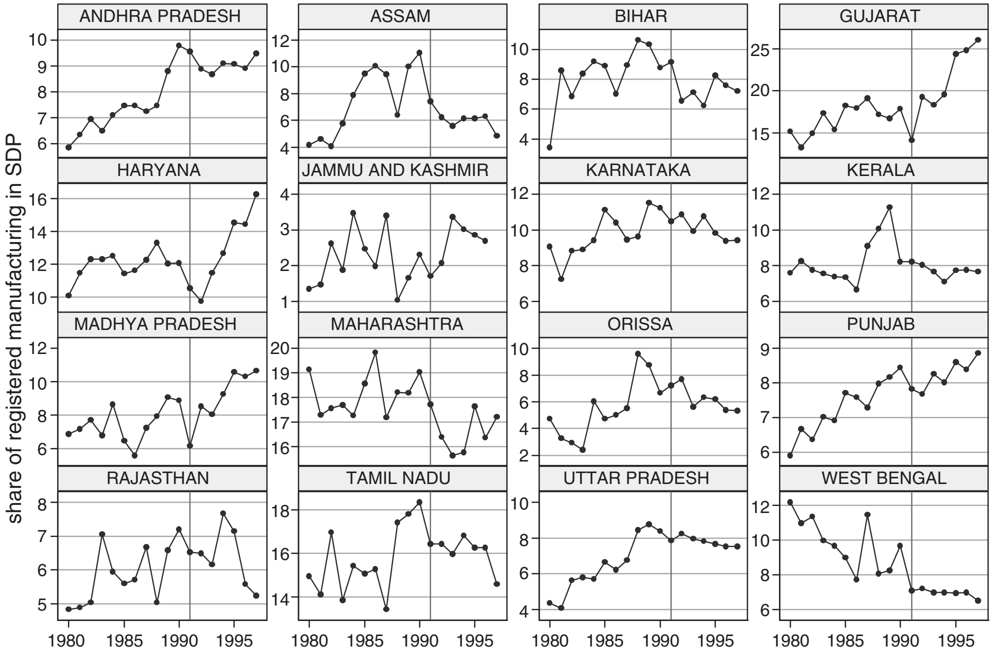

FIGURE 1. Share of registered manufacturing in state domestic product.

different years and in different industries, sometimes to an even greater extent. For instance, almost 80% of manufacturing value added in Assam can be attributed to industry 21 (food products), while over 50% of manufacturing value added in Orissa consists of industry 33 (basic metals and alloys).

At the national level, the performance of individual 2-digit industries is equally varied. Figure 2 shows the share of each 2-digit industry in total industrial value added. While most industries seem to have maintained their share of industrial value added, industries 23 and 27 (cotton textiles, and wood products) show decreasing shares over time, while industry 26 (textile products) experienced an increasing share over time.

Summary

There is a great variety across states and over time in India in terms of factor endowments and the performance of industries, both individually and in aggregate. This leads to the question of whether the variations in factor endowments are related to the differences in industrial performance.

II. EMPIRICAL STRATEGY

This section first outlines the theoretical background of the model, then presents the econometric specification; this is followed by a discussion of the measurement issues associated with calculating total factor productivity, and of estimation methods.

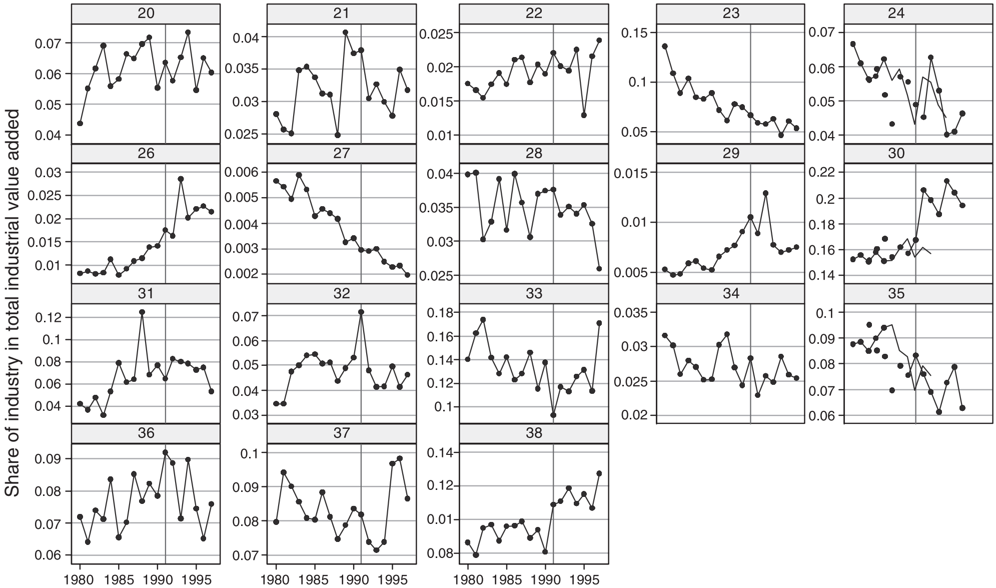

FIGURE 2. Share of industry in country-wide registered manufacturing.

Factor endowments and technology

The model is derived from neoclassical trade theory. The basic specification makes the usual assumptions of constant returns to scale, perfect competition and identical preferences across states. However, I allow for technology differences across states and industries. States are indexed by $z \in \{1, \ldots, Z\}$, goods by $j \in \{1, \ldots, N\}$, factors of production by $i \in \{1, \ldots, M\}$, and time by t.

Each state is endowed with an exogenous vector of factors of production, v_{zt}. I assume Hicks-neutral technology differences such that the production function takes the form (see Dixit and Norman 1980, p. 138) $y_{zjt} = \theta_{zjt} F_j(v_{zjt})$, where θ_{zjt} is the level of technology in industry j in state z in year t. The Hicks-neutral technology implies that technological differences affect the productivity of all factors of production in industry j in state z by the same proportion. The revenue function $r(\theta_{zt} p_{zt}, v_{zt})$ characterizes general equilibrium in production, where θ_{zt} is an $N \times N$ diagonal matrix of the technology parameters θ_{zjt}, and p_{zt} is a vector of final goods prices. As long as the revenue function is twice continuously differentiable, the vector of net output supplies $y(\theta_{zt} p_{zt}, v_{zt})$ is given by the gradient of $r(\theta_{zt} p_{zt}, v_{zt})$ with respect to p_{zt}.[5]

I followed Harrigan (1997) and Redding and Vera-Martin (2006) in assuming a translog revenue function, which is a flexible functional form that provides an arbitrarily close local approximation to any true underlying revenue function:

$$\begin{aligned} \ln r(\theta_{zt} p_{zt}, v_{zt}) = \beta_{00} &+ \sum_j \beta_{0j} \ln(\theta_{zjt} p_{zjt}) + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln(\theta_{zjt} p_{zjt}) \ln(\theta_{zkt} p_{zkt}) \\ &+ \sum_i \delta_{0i} \ln(v_{zit}) + \frac{1}{2} \sum_i \sum_h \delta_{ih} \ln(v_{zit}) \ln(v_{zht}) \qquad (1) \\ &+ \sum_j \sum_i \gamma_{ji} \ln(\theta_{zjt} p_{zjt}) \ln(v_{zit}) \end{aligned}$$

where $j, k \in \{1, \ldots, N\}$ index goods and $i, h \in \{1, \ldots, M\}$ index factors. Symmetry of cross effects requires that, for all j, k, i and h,

$$(2) \qquad \beta_{jk} = \beta_{kj} \quad \text{and} \quad \delta_{ih} = \delta_{hi}.$$

Linear homogeneity in v and p requires that

$$(3) \qquad \sum_j \beta_{0j} = 1 \qquad \sum_i \delta_{0i} = 1 \qquad \sum_j \beta_{jk} = 0 \qquad \sum_i \delta_{ih} = 0 \qquad \sum_i \gamma_{ji} = 0.$$

Differentiating ln $r(\theta_{zt}p_{zt}, v_{zt})$ with respect to each ln p_j gives the share of good j in GDP as a function of prices, technology and factor supply:

$$(4) \qquad S_{zjt} = \frac{p_{zjt}y_{zjt}(\theta_{zt}p_{zt}, v_{zt})}{r(\theta_{zt}p_{zt}, v_{zt})} = \beta_{0j} + \sum_j \beta_{jk} \ln(p_{zjt}) + \sum_j \beta_{jk} \ln(\theta_{zjt}) + \sum_i \gamma_{ji} \ln(v_{zit}).$$

This is a general equilibrium relationship between industry shares and prices, endowments and technology. Changes in the RHS variables have different effects in different industries, as captured here by the industry-specific coefficients.

Econometric specification

I first write equation (4) as

$$(5) \qquad S_{zjt} = \beta_{0j} + \sum_j \beta_{jk} \ln(p_{zjt}) + \sum_j \beta_{jk} \ln(\theta_{zjt}) + \sum_i \gamma_{ji} \ln(v_{zit}) + \varepsilon_{zjt},$$

where ε_{zjt} is a random error. Equation (5) can be estimated for each industry, pooling observations across states z and time t. However, one problem with estimating (5) is that prices of individual industries are not observable across states.

I followed Harrigan (1997) and Redding and Vera-Martin (2006) in treating price as a random variable with some estimable probability distribution. Thus, let

$$(6) \qquad \sum_j \beta_{jk} \ln(p_{zjt}) = \eta_{zj} + \mu_{jt} + u_{zjt}, \qquad u_{zjt} \sim N(0, \sigma_j^2),$$

such that the price of non-traded goods comprises state-industry fixed effects η_{zj}, industry-specific time dummies μ_{jt}, and a random component u_{zjt} and we get

$$(7) \qquad S_{zjt} = \beta_{0j} + \eta_{zj} + \mu_{jt} + \sum_j \beta_{jk} \ln(\theta_{zjt}) + \sum_i \gamma_{ji} \ln(v_{zit}) + \omega_{zjt},$$

where $\omega_{zjt} = \varepsilon_{zjt} + u_{zjt}$, and μ_{jt} is the time-specific effect of all goods prices. The state-industry fixed effect η_{zj} will also control for unobserved time-invariant differences across states that are allowed to have heterogeneous effects across industries. Equation (7) is our first estimated equation. It relates the share of an industry to factor endowments and technology, and industry–time and industry–state fixed effects.

The neoclassical model assumes free movement of factors among sectors. If reallocation of factors occurs with a lag in response to changes in technology, prices, and aggregate factor endowments, equation (7) will hold only after adjustment has taken place. With slow adjustment to equilibrium, output shares in the short run can be modelled as a dynamic model with a lagged dependent variable:

$$(8) \qquad S_{zjt} = \beta_{0j} + \eta_{zj} + \mu_{jt} + \lambda_j S_{zj,t-1} + \sum_j \beta_{jk} \ln(\theta_{zjt}) + \sum_i \gamma_{ji} \ln(v_{zit}) + \omega_{zjt},$$

where λ_j is the speed of adjustment, and the long run effect of a change in θ_{zjt} is given by $\beta_{jk}/(1-\lambda_j)$. Because symmetry requires $\beta_{jk}=\beta_{kj}$, it also requires $\lambda_j=\lambda_k$. Therefore, the coefficient on the lagged output share will be constrained to be the same for each equation when (8) is estimated. In short panels the OLS estimator of λ_j is biased and inconsistent. Following Anderson and Hsiao (1981), therefore, I took first differences in (8), yielding

$$(9)\qquad \Delta S_{zjt}=\mu_{jt}+\lambda_j\Delta S_{zj,t-1}+\sum_j \beta_{jk}\Delta\ln(\theta_{zjt})+\sum_i \gamma_{ji}\Delta\ln(v_{zit})+\Delta\omega_{zjt}.$$

The first-differenced lagged dependent variable $\Delta S_{zj,t-1}$ is instrumented with a two-period lag of the dependent variable, $S_{zj,t-2}$. As Baltagi (2005) shows, this is a valid instrument and yields a consistent estimate as long as ω_{zjt} are not serially correlated. Equation (9) is our second estimated equation.

Total factor productivity

In estimating equations (7) and (9), I also needed a measure of θ_{zjt}, the Hicks-neutral technology parameter. I calculated net-value added (NVA)-based total factor productivity (TFP) indices, using data on NVA, labour input and capital input. All values were deflated using industry-level price deflators.

Thus, suppose that value added NVA is a function of capital k and labour l. Suppressing industry and time subscripts for readability, for any given industry–time pair the index for any two states x and z is

$$(10)\qquad TFP_{xz}=\frac{NVA_x}{NVA_z}\left(\frac{\bar{l}}{l_x}\right)^{\sigma_x^l}\left(\frac{\bar{k}}{k_x}\right)^{1-\sigma_x^l}\left(\frac{l_z}{\bar{l}}\right)^{\sigma_z^l}\left(\frac{k_z}{\bar{k}}\right)^{1-\sigma_z^l},$$

where $\bar{l}$ and $\bar{k}$ are geometric averages over all the observations in the sample, $\sigma_z^l=(s_z^l+\bar{s}^l)/2$, where s_z^l is labour's share in output in state z. I calculated TFP relative to the geometric mean for each industry, so that, for state z, equation (10) simplifies to:

$$(11)\qquad TFP_z=\frac{\overline{NVA}}{NVA_z}\left(\frac{l_z}{\bar{l}}\right)^{\sigma_z^l}\left(\frac{k_z}{\bar{k}}\right)^{1-\sigma_z^l}.$$

This is the equation that is used to calculate TFP. It is a general superlative index number measure of TFP, meaning that it is exact for the flexible translog form.[6] Since the share of labour is relatively noisy and sometimes exceeds 1, I followed Harrigan (1997) in using a smoothing procedure. When the production function is translog and markets clear, labour's share in NVA of industry j at time t in state z is

$$(12)\qquad s_{zjt}^l=\alpha_{1zj}^l+\alpha_{2j}^l\ln\left(\frac{k_{zjt}}{l_{zjt}}\right).$$

If observed labour shares deviate from this equation by an i.i.d. error term, then the parameters of this equation can be estimated for each industry by regressing the share of labour on a set of state fixed effects and the capital–labour ratio. The fitted values from this equation are then used as the labour cost shares in the TFP equation (11).

Estimation

Since I was controlling for both time and state fixed effects, identification of the parameters of interest in (7) and (9) is through within-state time series variation. The translog revenue function implies the presence of cross-equation restrictions on the coefficients on TFP ($\beta_{jk} = \beta_{kj}$). These cross-equation restrictions imply that the errors are correlated across equations. Therefore, the appropriate way to estimate the system of equations is to use a restricted SURE (seemingly unrelated regressions) estimator. To take into account potential heteroscedasticity and serial correlation in the errors, I used an iterated SURE procedure with heteroscedastic-robust standard errors clustered by state. The resulting estimator is the maximum-likelihood SURE estimator.

In equation (7) I imposed the linear homogeneity assumptions above (equation (3)). I can therefore test whether or not these conditions hold. In terms of the model, this is a test of whether the revenue function is homogeneous of degree 1, or equivalently whether the sum of the factor endowment coefficients is equal to zero ($\sum_i \gamma_{ji} = 0$) in an unconstrained version of the model.

I also conducted tests for parameter stability over time, to test for changes in the impact of endowments and technology on industry shares caused by economic reform in 1985 and 1991. As discussed below, this was done by including a set of interaction terms, interacting a reform dummy with the RHS variables, and performing a χ^2-test on the joint significance of these interaction terms.

Finally, several additional explanatory variables were included in the basic specification as a robustness check on my results. I added the political history of the states to control for possible effects of different political parties on industrial structure, the Besley–Burgess (2004) labour regulation measure to account for pro-capital or pro-labour biases of state governments, and measures of market access calculated as distance-weighted state domestic product to account for proximity to markets and sources of supply. While several of the coefficients on these variables are statistically significant, they do not substantially change the following basic results on the relationship between industry shares, factor endowments and technology, and are omitted for brevity.[7]

There is a potential endogeneity problem in estimating equations (7) and (9) using state-level data, because of the potential for factor mobility across states. This poses no difficulty for crop area, which is immobile. It poses little difficulty for population as well, as labour mobility across states in India is relatively low: in the 1981 census, 95.2% of the Indian population was born in the state in which they were currently residing. The equivalent number in 1991 was 95.9%. Compare this with the United States, where in 2000 only 91.3% of the population were living the same state as they did in 1995 (see Franklin 2003). Munshi and Rosenzweig (2005) show that the low geographical mobility in India may be attributable to sub-caste networks which act as disincentives to movement.

Capital mobility across states in India is more of an unknown quantity. I experimented with using an instrumental variables approach to address the possible endogeneity of capital stock. However the instruments we used—installed electricity generating capacity and total bank credit in a state—proved to be not very strong instruments for the capital stock. To avoid weak instrument problems, I report only the uninstrumented results in the next section. I was not, therefore, able to obtain causal relationships between variables in the regression, although (similarly to Redding and Vera-Martin 2006) I could identify associations between the variables of interest.

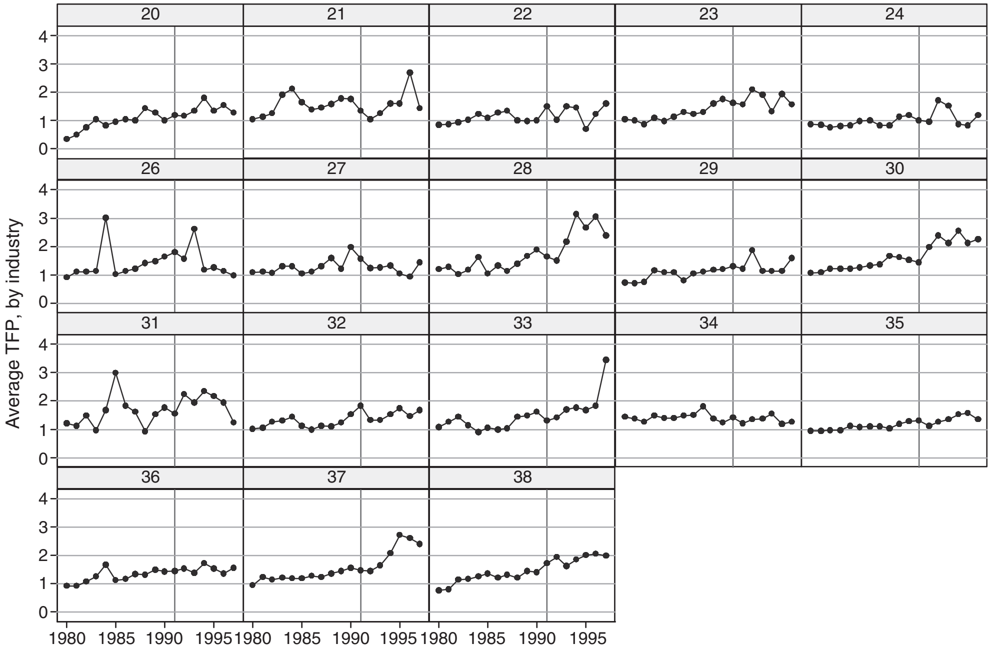

FIGURE 3. Time series of mean TFP, by industry.

III. RESULTS

Total factor productivity

The total factor productivity data are summarized in Figures 3 and 4. There is clearly great heterogeneity in performance across industries and states. From Figure 3 it can be seen that some industries are experiencing rapid improvements in technology, such as industries 20 (food products), 30 (basic chemicals), 37 (transport equipment) and 38 (other manufacturing). Many of the other industries do not appear to have experienced much change in TFP over the sample period; in industry 26 (textile products), TFP has actually declined in the post-reform period.

If we look at the mean of relative TFP across all industries over time weighted by industry value added (Figure 4), we find that TFP has been increasing over time, from 1.00 in 1980 to 2.00 in 1997. This corresponds to an average growth rate of almost 4.1%, which is similar to the recent results on TFP growth in India by Unel (2003), but slightly higher than that obtained by Rodrik and Subramanian (2004) for the same time period. There appears to be an increase in the growth rate of TFP over time; simple regression analysis shows the strongest evidence of a structural break in TFP growth occurring in the late 1980s.

These findings are consistent with the results of Aghion *et al.* (2006), who find a small mean effect of liberalization but substantial heterogeneity across states and industries. Krishna and Mitra (1998) present evidence that productivity growth increased in several industries in the post-reform period in India. This is not inconsistent with my own result, as I did find that some industries were experiencing more rapid TFP growth post-reform, for example industry 37 (transport equipment). Ahluwalia (1991) finds that TFP growth in India has been low throughout the post-independence period, growing by 0.2% per

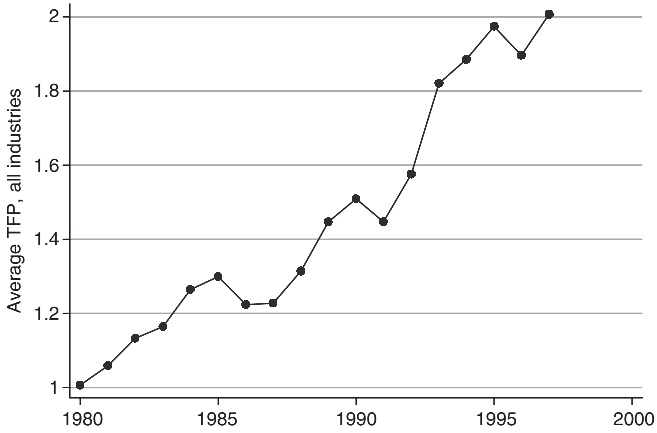

FIGURE 4. Time series of the mean of TFP.

year between 1959 and 1966, falling at a rate of 0.3% per year between 1967 and 1980 and increasing by 3.4% per year between 1981 and 1986.

One possible concern with my TFP measures is that the price deflators that I used to obtain real values are of questionable value in an economy where the artificially low price set by the authorities and the frequent shortage of intermediate inputs led to a flourishing black market for such inputs—a black market in which, clearly, the prices do not follow those set by the authorities. Therefore, the use of official prices will overstate real output, and hence may overstate TFP in the pre-reform period, although this depends on the wedge between official and true prices of both inputs and outputs. This is probably truer in the period before reform; but since the reform was a gradual process, some sectors and prices were probably highly distorted several years after the start of reforms.

Regression results

Table 3 presents the results for equation (7), with linear homogeneity and cross-equation constraints on the TFP terms. According to the theory, the own-TFP effect should be non-negative; superior technology in a sector should be positively related to greater share of that industry in the state. I found this to be true in all industries. This coefficient is positive and significant at the 10% level in all industries, while in 15 industries it is significant at the 1% level.[8]

Cross-industry TFP effects are included in the regression but are not reported in Table 3 for brevity. For cross-industry TFP effects there is a mix of positive and negative coefficients, as expected, since the underlying model is a general equilibrium model. Interpretation of this result is difficult since, with more than two factors and two goods, the predictions of the general equilibrium model hold only as averages or correlations.

We can test whether the TFP terms are jointly statistically significant. This amounts to testing the general neoclassical model, outlined above, against the more restrictive Heckscher–Ohlin model, which assumes identical technologies across all locations for each industry. If the Heckscher–Ohlin model is correct, the coefficients on TFP should be jointly statistically insignificant. I therefore performed a χ^2 test for the joint significance of all the TFP terms. The results are shown in Table 3. For all industries, the TFP terms are jointly significant at least at the 1% level. This result shows that technological

TABLE 3
BASIC SPECIFICATION WITH FACTOR ENDOWMENTS AND TECHNOLOGY DIFFERENCES WITH CROSS-EQUATION AND HOMOGENEITY CONSTRAINTS

Dependent variable	Industry 20 (1)	21 (2)	22 (3)	23 (4)	24 (5)	26 (6)	27 (7)	28 (8)	29 (9)	30 (10)	31 (11)	32 (12)	33 (13)	34 (14)	35 (15)	36 (16)	37 (17)	38 (18)
	Share of industry in state domestic product																	
Log real fixed capital	– 0.039	– 0.045	0.1	– 0.2	0.029	– 0.044	– 0.001	0.062	0.078	2.217	0.856	0.139	1.277	0.099	0.027	– 0.045	– 1.38	– 0.052
	(0.23)	(0.79)	(1.11)	(0.54)	(0.14)	(0.27)	(0.13)	(1.18)	(0.79)	(1.79)***	(1.78)***	(1.28)	(3.30)*	(1.59)	(0.16)	(0.26)	(1.32)	(1.19)
Log population	0.053	0.047	– 0.166	0.102	– 0.031	0.003	0.014	– 0.136	– 0.095	– 1.957	– 0.73	– 0.112	– 1.261	– 0.132	– 0.068	0.2	1.662	0.149
	(0.28)	(0.77)	(1.80)***	(0.32)	(0.13)	(0.017)	(1.22)	(2.31)**	(0.89)	(1.73)***	(1.58)	(1.03)	(3.40)*	(1.66)***	(0.34)	(1.17)	(1.27)	(3.38)*
Log crop area	– 0.014	– 0.001	0.066	0.097	0.002	0.041	– 0.013	0.075	0.017	– 0.261	– 0.127	– 0.027	– 0.016	0.033	0.042	– 0.155	– 0.282	– 0.098
	(0.38)	(0.15)	(3.67)*	(0.76)	(0.039)	(1.73)***	(4.51)*	(2.52)**	(1.16)	(1.30)	(1.44)	(1.24)	(0.18)	(1.11)	(0.94)	(5.96)*	(0.90)	(9.47)*
Own TFP	0.187	0.148	0.181	0.417	0.191	0.179	0.016	0.187	0.056	1.038	1.212	0.242	0.397	0.365	0.863	0.654	0.666	0.09
	(1.74)***	(6.60)*	(5.29)*	(4.58)*	(2.90)*	(3.13)*	(4.07)*	(3.86)*	(2.94)*	(5.05)*	(2.43)**	(3.97)*	(3.35)*	(8.05)*	(7.37)*	(2.91)*	(1.68)***	(3.47)*
Constant	1.037	0.397	0.539	2.496	– 0.143	0.307	0.005	0.249	– 0.458	– 12.61	– 5.158	– 0.078	– 6.553	– 0.358	0.588	1.28	8.254	0.233
	(1.20)	(1.36)	(1.01)	(1.03)	(0.13)	(0.30)	(0.097)	(0.92)	(0.76)	(1.61)	(1.82)***	(0.14)	(2.88)*	(0.95)	(0.60)	(1.47)	(1.35)	(0.80)
Observations	147	147	147	147	147	147	147	147	147	147	147	147	147	147	147	147	147	147
Chi-squared test of TFP	156.51*	105.5*	54.92*	75.13*	31.23*	115.76*	31.21*	40.06*	39.99*	143.72*	59.33*	60.23*	101.5*	250.89*	105.86*	25.77*	26.71*	43.81*
Sum of endowment coefficients	0.827	– 1.147	0.971	– 3.648	– 0.151	– 5.363	0.164	– 1.873	– 2.396	4.646	– 14.00	0.488	3.880	– 0.782	– 0.274	2.271	15.251	0.249
Z-stat.	1.1	– 2.96*	1.47	– 0.81	– 0.12	– 4.12*	1.63	– 3.38*	– 2.63*	1.09	– 4.95*	0.83	3.57*	– 1.21	– 0.22	2.5*	1.9	0.63

Notes:
Absolute values of z-statistics in parentheses.
***Significant at 10%; **significant at 5%; *significant at 1%.
Each column is run as an equation in a system, with state and year fixed effects. Estimation method is iterated SURE with linear homogeneity and cross-equation TFP constraints. Standard errors are robust to heteroscedasticity and are clustered by state.
The dependent variable is the share of the industry in total state domestic product. 'Own TFP' refers to the log of TFP in that industry; cross-industry TFP is included in the regression but not reported. The sum of endowment coefficients is the sum of coefficients on real fixed capital, population and crop area, if the regression is run without imposing the restriction that they sum to zero. The Z-stat. is the Z-stat. of the test that the sum of the endowment coefficients is equal to zero, when the regression is run without imposing that restriction. The chi-squared test of TFP is a test of the joint significance of all the TFP terms. See the Data Appendix for details of the construction and sources of the variables.

differences across industries and locations have a statistically significant relationship with the share of an industry in a state.[9]

For factor endowments the results are mixed. The endowment variables are highly significantly associated with industry share in industries 33 (basic metals) and 37 (transport equipment), and are marginally significant in several other industries. The sign of the coefficients suggests that industries 30 (chemicals), 31 (rubber and plastic) and 33 (basic metals) are associated positively with capital stock, but negatively with labour. While we should not draw too strong a conclusion from this result, because the relationship between factor endowments and industry share hold only as correlations with more than two goods and two factors, it is at least in accord with our prior that heavy industries are capital-intensive. If we divide industries into light industries (industries 20–29) and heavy industries (industries 30–37), we can see that crop area is more significantly related to light industries than to heavy industries, whereas capital stock is not significantly related to any light industry but is significantly related to several heavy industries. Hence there is some indication that capital endowments matter more in heavy industries, and land matters more in light industries.

Table 3 also reports the test of linear homogeneity of the revenue function. The null hypothesis of linear homogeneity is rejected at the 5% level for 7 out of 18 industries. In 5 of these industries (21: food products, 26: textiles, 28: paper products, 29: leather products and 31: rubber and plastic) the sum of endowment coefficients is significantly less than 0; while in the other two industries (33: basic metals and 36: machinery and equipment) it is significantly greater than 0.

Table 4 shows the results of including a lagged dependent variable in the regression to take into account slow adjustment. The coefficient on the lagged dependent variable is positive and highly significant, but quite small (0.119). This suggests that adjustment of industrial output to shocks occurs quite rapidly. Even in the short run, own TFP is highly significant and positively related to industry share in all industries. The joint effect of the TFP of all industries together is also highly significant, suggesting that technological differences across industries and states are significantly related to industry shares.

Turning to factor endowments, it is apparent that in the short run factor endowments are more strongly related to heavy industries (industries 30–37) than to light industries (industries 20–29), since among heavy industries there are 8 significant endowment coefficients as opposed to only 4 among the light industries. Most heavy industries are positively related to capital stock but negatively related to crop area. This result is again in accord with our theoretical priors, but it is different from Harrigan (1997), who finds that factor endowments are not significantly related to industry share in the slow adjustment model. My significant results on factor endowments, and the small coefficient on the lagged dependent variable, suggest that industrial output adjusts to shocks quite rapidly in India.

Table 4 also shows the results of my test for linear homogeneity of the revenue function. In this dynamic specification, there is only one industry (28: paper products) where the sum of endowment coefficients is significantly less than 0 at the 5% level. This result, together with those of the static model, suggests that the dynamic model fits the linear homogeneity assumption better than the static model does.

Testing for structural breaks

Another specification test that I performed was for structural breaks in the data. There are two candidates for the time of the structural break: the reform initiated by Rajiv

TABLE 4

SLOW ADJUSTMENT MODEL WITH LAGGED DEPENDENT VARIABLE

	Industry																	
	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	37	38
	Share of industry in state domestic product																	
Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Log real fixed capital	– 0.013	– 0.077	0.104	0.097	0.138	– 0.002	0.003	– 0.121	– 0.017	1.295	0.228	0.081	0.673	0.009	0.187	0.004	– 0.117	– 0.036
	(0.097)	(1.71)***	(0.94)	(0.59)	(1.58)	(0.038)	(0.26)	(1.46)	(0.68)	(1.57)	(0.79)	(1.70)***	(3.08)*	(0.20)	(1.81)***	(0.030)	(0.58)	(0.61)
Log population	– 0.015	0.075	– 0.11	– 0.105	– 0.181	0.013	0.012	0.16	0.01	– 1.163	– 0.595	0.012	– 0.722	0.071	– 0.113	0.633	0.115	0.142
	(0.10)	(1.76)***	(0.94)	(0.51)	(1.55)	(0.27)	(0.98)	(1.70)***	(0.39)	(1.51)	(1.48)	(0.37)	(3.22)*	(1.35)	(0.81)	(4.41)*	(0.44)	(2.33)**
Log crop area	0.028	0.002	0.007	0.007	0.043	– 0.011	– 0.015	– 0.039	0.007	– 0.132	0.368	– 0.094	0.048	– 0.08	– 0.074	– 0.637	0.001	– 0.106
	(0.59)	(0.22)	(0.32)	(0.096)	(1.18)	(0.69)	(7.04)*	(1.33)	(0.37)	(0.64)	(1.29)	(4.20)*	(0.91)	(4.60)*	(1.17)	(16.8)*	(0.012)	(14.7)*
Own TFP	0.463	0.133	0.153	0.382	0.28	0.173	0.018	0.19	0.024	0.694	1.281	0.3	0.366	0.326	0.996	0.700	0.373	0.103
	(5.46)*	(6.08)*	(4.81)*	(5.60)*	(5.79)*	(3.94)*	(3.39)*	(4.02)*	(2.45)**	(4.99)*	(2.85)*	(5.53)*	(3.00)*	(9.59)*	(6.80)*	(3.26)*	(2.63)*	(6.68)*
Lagged dependent variable	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*	(3.74)*
Constant	– 0.016	0.022	– 0.005	– 0.066	0.028	– 0.037	0.002	– 0.02	0.012	– 0.018	0.066	0.101	– 0.008	– 0.028	– 0.039	– 0.013	0.05	– 0.029
	(0.32)	(1.18)	(0.21)	(0.43)	(0.50)	(1.26)	(0.85)	(1.04)	(0.90)	(0.11)	(0.62)	(2.61)*	(0.11)	(1.19)	(0.48)	(0.24)	(0.80)	(2.01)**
Observations	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Chi-squared test of TFP	87.75*	465.83*	225.53*	249.94*	49.25*	367.97*	44.5*	203.51*	15.51**	113.71*	153.13*	101.84*	60.93*	53.97*	237.86*	58.16*	70.71*	110.63*
Sum of endowment coefficients	– 0.226	– 0.436	– 1.032	– 1.928	– 0.623	– 0.937	0.352	– 4.490	– 0.623	9.743	– 9.629	3.135	5.530	0.093	0.676	– 3.783	– 2.726	0.828
Z-stat.	– 0.11	– 0.35	– 0.48	– 0.33	– 0.26	– 0.37	1.52	– 2.03**	– 1.05	1.22	– 1.19	1.84	1.53	0.07	0.27	– 1.36	0.71	0.76

Notes:

Absolute values of Z-statistics in parentheses. ***Significant at 10%; **significant at 5%; *significant at 1%.

The coefficient on the lagged dependent variable is constrained to be identical across all industries. Each column is run as an equation in a system, with state and year fixed effects. Estimation method is iterated SURE with linear homogeneity and cross-equation TFP constraints. Standard errors are robust to heteroskedasticity and are clustered by state. The dependent variable is the share of the industry in total state domestic product. 'Own TFP' refers to the log of TFP in that industry; cross-industry TFP is included in the regression but not reported. The sum of endowment coefficients is the sum of coefficients on real fixed capital, population and crop area, if the regression is run without imposing the restriction that they sum to zero. The Z-stat. is the Z-stat. of the test that the sum of the endowment coefficients is equal to zero, when the regression is run without imposing that restriction. The chi-squared test of TFP is a test of the joint significance of all the TFP terms. See the Data Appendix for details of the construction and sources of the variables.

Gandhi in 1985, and the more general reform begun in 1991. One can think of the period 1985 and before as pre-reform, 1986–1991 as a transitional period and 1992 onwards as the post-reform period. Consider first the possibility of a structural break in 1985. This can be tested against the null of no structural breaks by running the following regression:

$$S_{zjt} = \beta_{0j} + \eta_{zj} + d_{jt} + \delta_{zj}[R \times \eta_{zj}] + \sum_j \beta_{jk} \ln(\theta_{zjt}) + \sum_i \gamma_{ji} \ln(v_{zit}) + \sum_j \varphi_{jk}[R \times \ln(\theta_{zjt})] + \sum_i \phi_{ji}[R \times \ln(v_{zit})] + \omega_{zjt}, \tag{13}$$

where R is an indicator variable taking value 0 if the observation is from before 1986, and 1 if the observation is from after 1985. The coefficients on the interaction terms represent the change in the impact of that variable after the year in question. A χ^2-test of the joint significance of the coefficients ϕ_{ji} in equation (13) is a test of whether the relationship between factor endowments and industry share, differs before and after 1985. Similarly, the joint significance of the coefficients φ_{jk} in equation (13) is a test of whether the relationship between technology and industry share, differs across these time periods. To test for the presence of a structural break in 1991, I estimated the same equation, replacing R with an indicator variable to divide the sample into Before and After 1991. Since my results for the static and dynamic models are not very different, I restrict my attention in this subsection to the static model, without the lagged dependent variable.[10]

Table 5 presents the results of the tests for structural breaks in the relationship between industry shares, factor endowments and TFP. The table shows an interesting pattern of results. Looking first at factor endowments, there is evidence of at least one structural break between the two years considered for all but five industries (20: food products, 26: textiles, 27: wood products, 30: basic chemicals and 38: other manufacturing). However, only in the two machinery and equipment industries (35 and 36) is there evidence of structural breaks in both years.

The timing of the break also differs across different types of industry. In what I call light industries (20–29), there is stronger evidence of structural breaks in 1991 than in 1985, whereas in what I call heavy industries (30–37), there is stronger evidence of structural breaks in 1985 than in 1991. This suggests that the early reforms of Rajiv Gandhi had a larger impact on heavy industries than on light industries, for which the major reform was the 1991 reform. This is consistent with the liberalization of the capital and intermediate goods sectors but not the consumption goods sectors in the 1980s. Only in the post-1991 reforms was there de-licensing that affected most of the industries in the economy.

There are fewer such patterns in the tests for structural breaks in the relationship between industry share and TFP. In almost every industry there is strong evidence of a structural break in the relationship between TFP and industry share in both 1985 and 1991. Therefore there is evidence that the relationships found in the previous section are not stable over time. I followed up the results in Table 5 by running the baseline estimated equation (7) for each of the three subsamples defined above, to see how the pattern of coefficient significance varies across the different time periods.

The results of these regressions are reported in Table 6. The TFP terms are always jointly significant in every industry in every subsample; technology is strongly associated with industry shares, irrespective of whether the economic system is one of state planning (before 1986), free markets (after 1991) or transition (1986–1991). The only exceptions to this are industries 27 (wood products), 28 (paper products) and 29 (leather products) in

TABLE 5
TEST OF STRUCTURAL BREAKS IN 1985 AND 1991

	Chi-squared			
	Endowments		TFP	
Industry	(1) 1985	(2) 1991	(3) 1985	(4) 1991
20	0.22	3.66	145.4*	96.2*
21	6.46***	4.42	19.6**	89.5*
22	2.13	15.98*	18.3**	29.7*
23	2.18	22.20*	93.4*	13.0
24	6.66***	0.28	30.3*	396.7*
26	1.97	4.36	44.7*	82.4*
27	3.56	0.03	22.0*	99.1*
28	3.59	2.43	164.5*	61.4*
29	1.97	37.45*	9.0	28.5*
30	2.41	4.11	154.1*	32.5*
31	5.18	28.07*	27.7*	82.8*
32	0.61	6.89***	197.5*	254.9*
33	14.29*	0.64	209.2*	232.4*
34	68.03*	0.51	35.2*	79.4*
35	13.80*	35.82*	25.9*	143.9*
36	12.50*	7.58***	133.7*	41.5*
37	19.95*	0.48	40.9*	16.3**
38	1.37	1.05	83.7*	549.5*

Notes:
***Significant at 10%; **significant at 5%; *significant at 1%.
The estimation method is iterated SURE with heteroskedastic robust standard errors clustered by state. The full specification, including endowments, TFP, and state and year effects, and a full set of interactions for the structural break in either 1985 or 1991, is run.
'Endowments' is the test of the joint significance of structural breaks in factor endowments.
TFP is the test of the joint significance of structural breaks in TFP. The degrees of freedom differ between the endowment and TFP tests, so the chi-squared statistics are not strictly comparable between endowments and TFP.

the transitional period between 1986 and 1991, where TFP was not or was only marginally significantly related to industry shares.

Somewhat differently, we see much more heterogeneity in the relationship between factor endowments and industry share. There is some evidence that factor endowments have a stronger relationship with industry share post-liberalization: not only are there more tests that are significant at at least the 10% level (9 in the post-liberalization period compared with 7 in the transition period and 6 in the pre-liberalization period), but also, the tests are significant at a much higher confidence level—at the 1% level 6 industries had a significant relationship with factor endowments post-liberalization, compared with just 2 in the transition period and 3 in the pre-liberalization period. The heterogeneity of results may be evidence of indeterminacy of the production structure when there are more goods than factors, as it becomes difficult to pin down the relationship between industries and factors across different time periods.

All in all, the results of Tables 5 and 6 show that the reform of the Indian economy throughout the period under study had extremely diverse and significant impacts on the

TABLE 6
ESTIMATION USING SUBSAMPLES DIVIDED INTO BEFORE LIBERALIZATION, TRANSITION PERIOD AND AFTER LIBERALIZATION

	Chi-squared					
	Endowments			TFP		
Industry	(1) 1980–85	(2) 1986–91	(3) 1992–97	(4) 1980–85	(5) 1986–91	(6) 1992–97
20	2.73	0.54	1.18	458.55*	74.15*	45.81*
21	3.3	4.21	16.85*	424.88*	108.43*	16.85**
22	20.4*	7.95**	4.59	36.13*	56.68*	128.27*
23	0.99	1.03	4.35	38.81*	55.06*	41.01*
24	0.47	4.04	21.64*	25.65*	38.95*	407.32*
26	1.93	2.71	7.1**	27.57*	34.91*	43.29*
27	7.8**	0.65	24.97*	57.91*	15.15***	19.41**
28	3.85	5.51***	49.29*	46.95*	13.23	49.17*
29	4.13	1.45	2.03	226.47*	14.85***	115.12*
30	1.92	1.99	5.99***	641.1*	223.71*	525.91*
31	2.38	4.89***	9.04**	1159.4*	410.53*	346.45*
32	4.65***	5.64***	0.94	47.55*	819.59*	17.8**
33	3.96	18.09*	11.35*	399.28*	317.96*	462.16*
34	5.41***	4.85***	0.98	2296.9*	652.25*	132.02*
35	4.34	2.09	0.07	294.52*	115.26*	164.22*
36	81.87*	1.21	3.13	50.38*	28.81*	95.77*
37	0.09	13.4*	2.75	59.35*	98.33*	42.78*
38	19.98*	1.82	10.18*	84.21*	78.21*	264.69*

Notes:
***Significant at 10%; **significant at 5%; *significant at 1%.
The estimation method is iterated SURE with heteroscedastic robust standard errors clustered by state. The full specification, including endowments, TFP and state and year effects, is run for three subperiods: 1980–85, 1986–91, and 1992–97. The figures reported are chi-squared values for the test of the joint significance of endowments and of TFP. The degrees of freedom differ between the endowment and TFP tests, so the chi-squared statistics are not strictly comparable between endowments and TFP.

different industries in India.[11] The reform of the Indian economy has changed the relationship between factor endowments, technology and industrial structure. This is consistent with the idea that the relationship between these variables is different in a centrally planned economy from that in a market-orientated economy.

IV. SUMMARY AND CONCLUSIONS

The objective of this paper has been to explore the relationship between factor endowments, technology and industrial structure across states in India. To do so, I have used a neoclassical trade model, which has been used successfully in explaining industrial structure in more developed countries. This allows us to consider the extent to which such a neoclassical model can be successfully used for developing countries. My data-set, which is a panel of 16 states and 18 industries from 1980 to 1997, covers a period of change in the policy environment towards private economic activity in India. I was therefore able to consider the impact of these economic reforms on the relationship between factor endowments, technology and industrial structure.

The main results are as follows. First, I find evidence of improvements in average TFP over time. However, there is also great heterogeneity in TFP performance across states and industries, with some industries not exhibiting any growth in TFP. Second, both factor endowments and technology are strongly related to the location of industries. There is evidence that land is negatively, and capital stock positively, related to heavy industry. Higher levels of technology in an industry are associated with a larger share of that industry in a state.

Third, there is strong evidence of structural breaks in the relationship between technology, factor endowments and industry share over the period under study. This has been a period of reform in the Indian economy, with the initial reforms of Indira Gandhi in 1980 and Rajiv Gandhi in 1985 and the more general liberalization in 1991. These changes correspond to a shift from a centrally planned economy to a more market-orientated economy. Factor endowments are more significantly related to industry shares post-reform.

In conclusion, the neoclassical model, when suitably extended, provides a relatively successful explanation of the pattern of production across regions within a developing country such as India. Its application is not therefore limited to the developed world, and it provides a suitable framework for exploring how market-orientated reforms have changed the relationship between industrial structure, technology and factor endowments.

Data Appendix

The data come from many sources. My data-set builds on Ozler *et al.* (1996) and Besley and Burgess (2004).

State population data used to express magnitudes in per capita terms come from the 1971, 1981, 1991 and 2001 censuses (*Census of India*, Registrar General, and Census Commissioner, Government of India) and have been interpolated between census years. State domestic product comes from *Estimates of State Domestic Product* published by Department of Statistics, Ministry of Planning, Government of India.

Industry data are from the Indian Annual Survey of Industries (ASI), Central Statistical Office, Department of Statistics, Ministry of Planning, Government of India. Data are available at the 3-digit level, following the National Industrial Classification (NIC). The data in the ASI are for registered manufacturing, defined as firms with 20 or more workers but no electrical power, or firms with 10 or more workers and electrical power. There is a change in industrial classification in 1987 and, in order to match the 1970 and 1987 NICs, I aggregated a small number of 3-digit industries. I excluded miscellaneous manufacturing industries, as these are likely to be heterogeneous across states. The industries 'Minting of Currency Coins' and 'Processing of Nuclear Fuels' were also excluded, as outcomes in these industries are likely to be determined by special considerations. This left a total of 138 industries, which were then aggregated to the 2-digit level.

The dependent variable in the regressions is the share of industry value added in state domestic product. Industry value added is calculated as the sum of net value added and depreciation; this is divided by state domestic product to get the share of an industry. Fixed capital also comes from the ASI; it represents the depreciated value of fixed assets owned by the factory on the closing date of the accounting year.

To calculate total factor productivity using the net value added approach, the following industry-level variables from the ASI were used:

- *Net value added*: the increment to the value of goods and services contributed by the factory
- *Fixed capital*: the depreciated value of fixed assets owned by the factory
- *Workers*: all persons employed in any kind of work connected to the manufacturing process.

The industry level share of labour in value added was calculated as the sum of emoluments plus welfare expenditure, divided by net value-added. Net value added, fixed capital and payments to labour were deflated by the industry-level price deflator for Machinery and Transport Equipment, obtained from the *Indian Handbook of Industrial Statistics* (various issues), 1980–97.

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NOTES

1. This is in line with the injunction in Leamer and Levinsohn (1995) to 'estimate, don't test' economic models.
2. There are also benefits of using within-country rather than cross-country data, since (i) within-country data are more likely to be comparable, (ii) any measurement error biases may be expected to work in a similar direction, and (iii) more generally the assumptions of the basic model are more likely to hold across states within a country than across different countries. Also, it relates to the original work of Ohlin, who notes in the preface to *The Theory of Trade* that: 'international trade is only a special case of what could be called interlocal trade, that is, exchange between locations which are characterised by incomplete mobility of factors and commodities between them' (Ohlin 1924).
3. There is also controversy regarding the precise timing of the takeoff of the Indian economy in terms of more rapid economic growth; see e.g. Rodrik and Subramanyam (2004) for a view on the timing of the takeoff, and Wallack (2003) for an analysis of the timing of structural breaks in the Indian macroeconomy.
4. Throughout this paper, I use the term 'manufacturing' to mean registered manufacturing.
5. A sufficient condition for the revenue function to be twice continuously differentiable and for production patterns to be determinate is that there are at least as many factors as goods: $M \geqslant N$. If there are more goods than factors, $N > M$, production structures may still be determinate if there are differences in technologies or relative prices across states. If the production structure is indeterminate, then my estimated equation will perform poorly in explaining industry share across states, in terms of having statistically insignificant right-hand-side variables.
6. Caves *et al.* (1982a, b) show how we can obtain the productivity index (10). Griffith *et al.* (2004) consider alternative ways of measuring TFP.
7. These additional results are available from the author upon request.
8. There is a potential endogeneity problem with the own-TFP effects, as shocks to own TFP would also affect the share of an industry in GDP. I regressed equation (7) using IV, instrumenting TFP for each industry in each state, with the average of TFP in that industry across all other states (following Harrigan 1997). The instrument has high explanatory power in the first-stage regression, and passes the Hausman (1978) test of no systematic difference between IV and OLS estimates. This suggests that biases resulting from endogeneity problems are not severe. Another alternative would be to follow Nickell *et al.* (2004) in smoothing TFP using a Hodrick–Prescott filter.
9. This is one advantage of this approach as opposed to that of Harrigan and Zakrajsek (2000) or Redding and Vera-Martin (2006); the use of separate measures of technology in the regression allows us to disentangle the effects of technology from other effects that are captured by the state and time fixed effects.
10. There are several other tests that can be performed using this framework. For instance, one can test whether or not there are structural breaks in both 1985 and 1991, against various alternative nulls, of no breaks, or a single break in 1985 or 1991. Finally, one can also test whether all interaction terms, including the state fixed effects, are jointly significant; this would be equivalent to a Chow (1960) test for structural breaks.
11. See Aghion *et al.* (2006) on the uneven impact of liberalization on productivity and output across Indian industries.

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