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Abstract

This paper studies the linkage between structural coherence and economic growth. Structural coherence is defined as the degree that a country's industrial structure optimally reflects its factor endowment fundamentals. The paper found that at least for the overall capital, the shares of capital intensive industries were significantly bigger with higher initial capital endowment and faster capital accumulation. Moreover, there is a positive relationship between a country's aggregate output growth and the degree of structural coherence. Quantitatively, the structural coherence with respect to the overall capital explains about 30% of the growth differential among sample countries.

JEL Classification Numbers: O1, O4, E2

Keywords: Structural Coherence, Economic Growth, Structural Change, Factor Endowment, Capital Accumulation

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I. INTRODUCTION

Although neoclassical growth models generally feature balanced growth path, in reality the industrial composition of economies experience continuous shifts, accompanied by massive reallocation of labor and production resources across sectors. Investigations on the causes of structural change have been mostly theoretical. A recent example is Acemoglu & Guerrieri (2008), who modeled structural change as a result of capital accumulation. In their two-sector model, as capital becomes more abundant output increases in the capital-intensive sector, while the direction of employment composition change depends on the elasticity of substitution between sectors.[1] Ju, Lin & Wang (2008), focusing more on developing countries, arrived at similar conclusions: as capital accumulates, a country's industrial structure "upgrades" towards more capital-intensive industries. Moreover, they argue that when the industrial structure is not coherent with the capital endowment level, it can lead to suboptimal economic growth performance.[2]

Ju, Lin & Wang's prediction about the linkage between structural coherence and economic growth can also be derived from Acemoglu & Guerrieri (2008)'s framework, though not explicitly discussed in their paper. The intuition is straightforward: in Acemoglu & Guerrieri's paper, output composition change towards capital-intensive industries is the natural result of the agents' optimal decision as capital accumulates. Hence, any arrangement that obstructs the structural change process towards alignment with factor endowments is not an optimal choice and therefore has a negative impact on long-run growth. Although it is beyond the scope of the current study to identify specific causes of structural incoherence, the incoherence between industrial structure and factor endowment can be caused by such factors as over-restrictive labor market regulation, lack of competition in certain industries, and technology barriers, as identified in related literature.[3]

The major goal of this paper is to empirically examine the relationship between capital endowment and industrial structure, and to estimate structural coherence' impact on growth. Here is an overview of the main empirical results. For the overall capital, the data shows that the capital-intensive industries' output and employment sizes are larger when capital endowment is higher, and growth in capital endowment also leads industrial structure to shift towards capital-intensive industries. Similar results apply, to various degrees, to detailed

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[1] There are other explanations of structural change, to be sure. On the supply side, for example, Ngai & Pissarides (2007) models industrial composition change as a result of uneven rates of TFP growth across sectors. The demand side literature explains structural change as a combined result of nonhomothetic consumer preference and income growth (Echevarria (1997), Laitner (2000), Buera & Kaboski (2007)). Thus in the empirical regressions, I will control for these other factors that potentially affect structural change process.

[2] In an earlier work, Hollis Chenery (1979) made a similar point. He argues that countries that are short on capital, in considering their development policy, should choose industries and production techniques that have low capital to output ratio.

[3] The linkage between structural change and aggregate economic performance have been discussed in some recent macroeconomic literature, such as, Nickell, Redding & Swaffield (2004), Rogerson (2007), van Ark, O'Mahony & Timmer (2008), and Baily (2001).

types of physical capital.[4] In terms of the relationship between structural coherence and growth, the results show that a country's aggregate growth performance is significantly and positively associated with the coherence level between industrial structure and capital endowment. In the country-level regression, structural coherence related to the overall capital explains about 30% of the variation in country GDP growth. The industry-level regression indicates an effect of similar magnitude. Moreover, the industry-level results are mostly robust to changing the measurement of capital intensity and to controls for other industry characteristics and structural change determinants.

The paper is related to a large empirical international trade literature that aims to test Heckscher-Ohlin theorem and Rybczynski theorem.[5] Recent examples of this literature are Harrigan (1997), Reeve (2002), Romalis (2004) and Schott (2003). Some of these papers found that endowment and change of endowment in physical capital and/or human capital has a significant impact on trade patterns or industrial structure.[6] There are obvious differences in terms of the underlining theory between the present paper and most of that literature. Sectoral structural change induced by factor endowment change is a process independent of whether the country is an open economy or not. Thus the present paper covers all industries in an economy, regardless of whether the products are considered tradable or not. In terms of methodology, most of the endowment-related trade studies assume identical capital intensities of industries across countries, or at least the same capital intensity ranking in different countries. Thus the literature often uses industry characteristics in one country as proxies for all other countries. Though a reasonable assumption when countries are relatively similar, this assumption is not necessarily true as will be shown in Section 3.[7] This paper allows the capital intensity ranking of industries to change across countries and over time.

The paper is also related to empirical investigations of allocative efficiency across industries and firms (e.g., Bartelsman, Haltiwanger & Scarpetta (2008), Arnold, Nicoletti & Scarpetta (2008)). This strand of literature mainly focuses on efficiency in resource allocation according to firm/industry's productivity level, instead of resource allocation according to consistency with factor endowments. To my best knowledge, the present paper

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[4] My focus in this paper is mostly fixed physical capital. The mechanism examined here can apply to intangible capital, too. Che (2009) argues that the increasing importance of intangible capital in the production process is a cause of sectoral structural change in advanced economies. However, the test on intangible capital is difficult to execute in a cross-country setting due to data limitations.

[5] These theorems state, respectively, that differences in countries' exports are determined by differences in their factor endowments, and that a rise in the endowment of a factor will lead to more than proportional output increase in sectors that use the factor intensively, given constant goods prices.

[6] Fitzgerald & Hallak (2002) gives an excellent review of recent empirical literature in trade that is related to factor endowments.

[7] Lewis (2006) shows that production techniques within the same industry vary even within US across different regions according to the production factor mix of the region. Scott (2003) finds that capital abundant countries tend to use more capital-intensive techniques in all industries.

is the first one to examine the impact of industrial structure-factor endowment coherence on economic growth.

The paper is organized as follows. Section 2 provides a simple theoretical framework to explain the relationship between capital endowment, structural coherence and growth. Section 3 discusses the data and defines measures of variables. Section 4 and 5 present the empirical models, at country and industry level respectively, and discuss the estimation results. More restrictions to the industry-level estimation and robustness checks are added in Section 6. Section 7 concludes.

II. An Illustrative Model

To examine the relationship between structural coherence and growth, consider a simple two-sector model adapted from Acemoglu & Guerrieri (2008). In the model economy, a single final good is produced by combining two sectoral goods, the elasticity of substitution between the two sectors equal to $\varepsilon \in [0, \infty)$:

$$Y_t = \left[\gamma_1 Y_{1,t}^{(\varepsilon-1)/\varepsilon} + \gamma_2 Y_{2,t}^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)}$$

where $\gamma_1 + \gamma_2 = 1$. There is one firm in each sector. Both sectors' production functions are Cobb-Douglas with capital and labor as production inputs:

$$Y_{i,t} = A_t K_{i,t}^{a_i} L_{i,t}^{1-a_i} \tag{1}$$

For simplicity, let's assume that the two sectors share the same productivity level, A_t, while Sector 1 is more capital-intensive than Sector 2, i.e., $a_1 - a_2 > 0$.

Let the price of the final good $P_t = 1$, then the prices for the two sectoral goods can be expressed as

$$P_{1,t} = \gamma_1 \left(\frac{Y_t}{Y_{1,t}} \right)^{-1/\varepsilon}, \text{ and } P_{2,t} = \gamma_2 \left(\frac{Y_t}{Y_{2,t}} \right)^{-1/\varepsilon}$$

Thus the direction of change in the ratio of nominal output between the two sectors, $\frac{P_{1,t} Y_{1,t}}{P_{2,t} Y_{2,t}}$, corresponding to a change in the real output ratio $Y_{1,t} / Y_{2,t}$ will depend on the value of ε. When $\varepsilon > 1$, the nominal output ratio moves in the same direction as the real output ratio, and the opposite is true for $\varepsilon < 1$.

Assume that labor is freely mobile between the two sectors in any given period. Labor market clearing implies

$$L_{1,t} + L_{2,t} = \overline{L}_t \tag{2}$$

where $\overline{L}_t$ is the labor supply at time t, which is exogenously given.

Capital is also mobile across sectors. However, changes in the allocation of capital resource are costly. It manifests as a positive adjustment cost $G\left(K_{1,t} / K_{2,t} - s_t\right)$ whenever the ratio between the two sectors' capital differs from a predetermined value s_t, which may be equal to, say, some historical ratio between K_1 and K_2. Capital market clearing requires

$$K_{1,t} + K_{2,t} + G\left(K_{1,t} / K_{2,t} - s_t\right) = K_t, \tag{3}$$

where K_t is the aggregate capital stock at time t. $G(0) = 0,\ G' > 0,$ and $G'' \geq 0$. Specifically, assume that $G(\bullet)$ takes a quadratic form:

$$G\left(K_{1,t}, K_{2,t}\right) = \phi\left(\frac{K_{1,t}}{K_{2,t}} - s_t\right)^2 \tag{4}$$

where $\phi \geq 0$. The existence of adjustment cost introduces friction into the cross-sector movement of resources, thus can potentially alter the extent of sectoral structural change compared to the case of frictionless economy.

Assume that the markets are complete and competitive. The equilibrium of the economy can be solved as a social planner's problem that maximize the utility of the representative household, $\sum_{t=0}^{\infty} U\left(C_t\right)$, subject to the aggregate resource constraint for the economy: $C_t + K_{t+1} = Y_t + \left(1-\delta\right)K_t$.

Given capital stock K_t in each period, the intra-temporal component of the planner's problem is to solve

$$\max_{L_{1,t}, L_{2,t}, K_{1,t}, K_{2,t}} Y_t = \left[\gamma_1 Y_{1,t}^{(\varepsilon-1)/\varepsilon} + \gamma_2 Y_{2,t}^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)} \tag{5}$$

subject to (1), (2), (3), and (4).

Solving (5) requires the marginal products of capital and labor in the two sectors being equal, which implies:

$$\gamma_1 a_1 \left(\frac{Y_t}{Y_{1,t}}\right)^{1/\varepsilon} \frac{Y_{1,t}}{K_{1,t}} / \left[1 + \frac{2\phi}{K_{2,t}}\left(\frac{K_{1,t}}{K_{2,t}} - s_t\right)\right] = \gamma_2 a_2 \left(\frac{Y_t}{Y_{2,t}}\right)^{1/\varepsilon} \frac{Y_{2,t}}{K_{2,t}} / \left[1 - \frac{2\phi K_{1,t}}{K_{2,t}^2}\left(\frac{K_{1,t}}{K_{2,t}} - s_t\right)\right] \tag{6}$$

$$\gamma_1(1-a_1)\left(\frac{Y_t}{Y_{1,t}}\right)^{1/\varepsilon}\frac{Y_{1,t}}{L_{1,t}}=\gamma_2(1-a_2)\left(\frac{Y_t}{Y_{2,t}}\right)^{1/\varepsilon}\frac{Y_{2,t}}{L_{2,t}} \tag{7}$$

Denote the share of capital and labor allocated to the capital intensive sector (Sector 1) as

$$\lambda_t=\frac{K_{1,t}}{K_{1,t}+K_{2,t}},\ \xi_t=\frac{L_{1,t}}{L_{1,t}+L_{2,t}}$$

Then (6) and (7) imply that

$$\lambda_t+\frac{2\phi\frac{\lambda_t}{1-\lambda_t}\left(\frac{\lambda_t}{1-\lambda_t}-s_t\right)}{K_t-\phi\left(\frac{\lambda_t}{1-\lambda_t}-s_t\right)^2}=\left[1+\frac{\gamma_2 a_2}{\gamma_1 a_1}\left(\frac{Y_{2,t}}{Y_{1,t}}\right)^{1-1/\varepsilon}\right]^{-1} \tag{8}$$

$$\begin{aligned}\xi_t&=\left[1+\frac{\gamma_2(1-a_2)}{\gamma_1(1-a_1)}\left(\frac{Y_{2,t}}{Y_{1,t}}\right)^{1-1/\varepsilon}\right]^{-1}\\&=\left[1+\frac{a_1(1-a_2)}{a_2(1-a_1)}\frac{(1-\lambda_t)K_t-2\phi\frac{\lambda_t}{1-\lambda_t}\left(\frac{\lambda_t}{1-\lambda_t}-s_t\right)}{\lambda_t K_t-\phi\lambda_t\left(\frac{\lambda_t}{1-\lambda_t}-s_t\right)^2+2\phi\frac{\lambda_t}{1-\lambda_t}\left(\frac{\lambda_t}{1-\lambda_t}-s_t\right)}\right]^{-1}\end{aligned} \tag{9}$$

Notice that $Y_{1,t}/Y_{2,t}$ is equal to

$$\lambda_t^{a_1}(1-\lambda_t)^{-a_2}\xi_t^{1-a_1}(1-\xi_t)^{a_2-1}K_t^{a_1-a_2}\overline{L}_t^{a_2-a_1}, \tag{10}$$

Therefore, given the resource allocation λ_t and ξ_t unchanged, an increase in K_t will disproportionately raise the real output of Sector 1 over Sector 2, and the opposite is true when labor endowment increases. Plugging (10) into (8) and taking derivative of both sides of (8) with respect to K_t, we arrive at the following proposition describing the relationship between changes in cross-sector resource allocation and changes in aggregate capital stock in any given period.

PROPOSITION: *In the static equilibrium,*

$$\frac{\partial\ln\lambda_t}{\partial\ln K_t}=\frac{(1-\varepsilon)(a_1-a_2)(1-\lambda_t)}{(1-\varepsilon)(a_1-a_2)(\lambda_t-\xi_t)-1-\Phi_t}>0\Leftrightarrow\varepsilon>1 \tag{11}$$

where Φ_t, when $s_t = K_{1,t} / K_{2,t}$, can be expressed as

$$\Phi_t = \frac{2\phi}{(1-\lambda_t)}\left[1+\frac{\lambda_t^2}{(1-\lambda_t^2)}\right]\left[1-(1-\varepsilon)(a_1 - a_1\xi_t + a_2\xi_t)\right] \tag{12}$$

The proposition says that when the elasticity of substitution between sectors is greater than one (which is the relevant scenario in our empirical investigation as Section 4 and 5 will show), increasing aggregate capital stock will lead to capital being shifted to the capital intensive sector (Sector 1). From (9), we know that ξ_t is increasing in λ_t. Thus Sector 1's labor share will also increase with capital stock, when $\varepsilon > 1$. However, the degree of this shift is subdued by the presence of structural adjustment cost, as Φ_t is a positive function of ϕ and it is easy to see from (11) and (12) that

$$\frac{\partial \left|\partial \ln \lambda_t / \partial \ln K_t\right|}{\partial \phi} < 0 \tag{13}$$

What follows from (13), combined with (10), is that the sectoral structural change in terms of real output when capital stock increases is suppressed by the presence of structural adjustment cost:

$$\frac{\partial^2 \ln(Y_{1,t} / Y_{2,t})}{\partial \phi \partial \ln K_t} < 0, \text{ when } \varepsilon > 1.$$

The effect on the output of the final good is also straightforward. When $\phi = 0$, the resource allocation prescribed by the solution to (5) achieves the maximized value of Y_t given the amount of capital endowment. In other words,

$$\left.\frac{\partial Y_t}{\partial K_t}\right|_{\phi=0} = \max_{\lambda_t} \frac{\partial Y_t}{\partial K_t}.$$

Therefore, with positive structural adjustment costs, the increase in Y_t corresponding to an increase in capital stock is lower compared to the case of zero adjustment cost: $\left.\frac{\partial Y_t}{\partial K_t}\right|_{\phi>0} < \left.\frac{\partial Y_t}{\partial K_t}\right|_{\phi=0}$.

The main conclusion to draw from the theoretical discussion is two folds. First, increasing capital endowment is likely to be accompanied by structural change towards the capital intensive sectors and industries in terms of real output. The change of industrial composition in terms of employment and nominal output depends on the elasticity of substitution between

industries. If the elasticity is above unity, then nominal output shares and employment shares of capital-intensive industries will also rise as capital endowment increases. Second, if for any structural reasons the cross-sector reallocation of resources is hindered, then the industrial structure may become insensitive to the changes in factor endowment. And this lack of responsiveness in industrial structure can lead to suboptimal economic performance at the aggregate level. The subsequent part of the paper will empirically examine both predictions.

III. Data and Variables

The data used in this paper is from the EU KLEMS database sponsored by the European Commission. The database provides industry output, employment, price, capital stock and investment data from 1970 to 2005 for both EU countries and several non-EU countries.[8] Table 1 lists the industries covered, the cross-country median growth rates of their real output shares, employment shares and nominal output shares over the 35-year period, and the cross-country medians of industry's overall capital intensity.[9] Industries are sorted by their median real output share growth. It is worth noting that although the industrial composition change is different for each country, in general the real output composition is shifting towards service industries and a few more sophisticated manufacturing industries. This is consistent with the stylized facts about structural transformation documented in the existing literature about US and other advanced economies. Employment composition has a similar trend to real output composition, yet shows an even stronger shift towards service industries. The median growth rate for nominal output shares has the same sign as employment shares but for seven industries.

Consistent with common perceptions, some industries that are traditionally perceived as labor intensive, such as textile and food industries, have relatively low median capital intensity. Somewhat counter-intuitive, though, certain stereotypical "capital-intensive" manufacturing industries, such as machinery and basic metals, do not have particularly high median capital intensity according to Table 1; in contrast, service industries such as social and personal services, health, retail, finance and education show up as relatively capital intensive. The reason is that although these service industries are not intensive in machinery capital, they are generally more intensive in ICT capital and structure capital, thus boosting their overall capital intensity scores. The opposite is true for some basic manufacturing industries that rely heavily on machinery, but are not particularly intensive in the other two categories of capital. On the whole, there is a positive correlation between industry's median real output share growth and median overall capital intensity, with a correlation coefficient equal to 0.25 at 1% significance level.

8 The paper covers 15 countries: Australia, Austria, Denmark, Finland, Germany, Italy, Japan, Korea, Netherland, UK, USA, Czech, Portugal, Slovenia, and Sweden. Data for the last 4 countries is only available starting the mid 1990s.

9 Capital intensity is calculated as industry real capital stock over real output.

Table 1:Cross-country median industry size growth and capital intensity

Industry	Median share growth rate from 1970 to 2005			Median capital intensity (Overall capital stock/output)
	Real output share	Employment share	Nominal output share	
Textiles, Textile , Leather And Footwear	-1.323	-1.891	-1.673	0.512
Mining And Quarrying	-0.758	-0.781	-0.555	1.696
Coke, Refined Petroleum And Nuclear Fuel	-0.620	-0.853	-0.064	0.510
Food , Beverages And Tobacco	-0.431	-0.603	-0.584	0.436
Construction	-0.422	-0.301	-0.205	0.232
Wood And Of Wood And Cork	-0.325	-0.494	-0.385	0.508
Hotels And Restaurants	-0.299	0.519	0.017	0.708
Other Non-Metallic Mineral	-0.285	-0.671	-0.434	0.734
Manufacturing Nec; Recycling	-0.193	-0.399	-0.253	0.477
Pulp, Paper, Paper , Printing And Publishing	-0.175	-0.491	-0.231	0.538
Education	-0.119	0.283	0.189	1.493
Basic Metals And Fabricated Metal	-0.114	-0.552	-0.316	0.600
Retail Trade	0.008	0.155	-0.016	0.824
Sale And Repair Of Motor Vehicles And Motorcycles	0.037	0.088	0.026	0.616
Other Community, Social And Personal Services	0.043	0.414	0.399	1.209
Wholesale Trade And Commission Trade	0.106	0.005	0.001	0.550
Real Estate Activities	0.145	0.697	0.532	0.566
Transport And Storage	0.147	-0.017	0.099	1.868
Health And Social Work	0.152	0.633	0.514	0.921
Machinery, Nec	0.176	-0.299	-0.044	0.442
Chemicals And Chemical Products	0.197	-0.559	-0.081	0.754
Electricity, Gas And Water Supply	0.279	-0.383	0.194	3.424
Rubber And Plastics	0.301	-0.113	0.112	0.581
Transport Equipment	0.335	-0.264	0.064	0.510
Financial Intermediation	0.501	0.222	0.502	0.708
Electrical And Optical Equipment	0.715	-0.331	0.054	0.496
Renting Of M&Eq And Other Business Activities	0.826	1.218	0.979	0.555
Post And Telecommunications	1.199	-0.174	0.605	2.231

* Real output, employment and nominal output share growth is calculated as log (share) in 2005 minus log (share) in 1970. Capital intensity of industry is calculated as industry's real overall capital stock divided by real output. The table reports the cross-country medians of share growth and capital intensity for each industry.

Figure1 and Table 2 present the trend of aggregate labor income shares by country. In 13 out of the 15 countries covered, labor's share has declined over the sample period. This result is consistent with the fact that the industrial structure of the sample countries is moving towards more capital intensive industries.[10]

[10] The decline of labor income share in these countries has been documented in previous literature. See, for example, Blanchard (1997), Bentolila & Saint-Paul (2003), de Serres, Scarpetta & de la Maisonneuve (2002), and Arpaia, Perez & Pichelmann (2009).

Figure 1: Evolution of labor income share by country

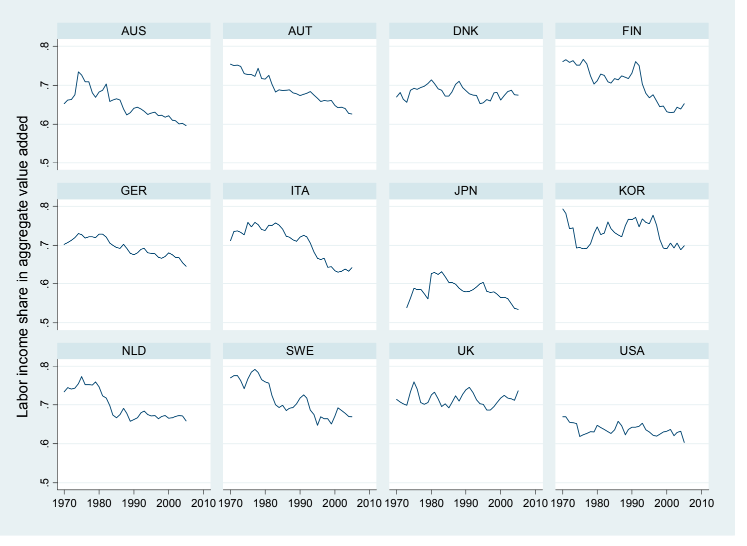


Table 2: Evolution of labor income share over time

	Aggregate labor income share			
country	1975	1995	2005	% change: 1975 - 2005
AUS	0.727	0.629	0.596	-18.019
AUT	0.728	0.666	0.627	-13.874
CZE	n.a.	0.567	0.596	5.115
DNK	0.692	0.656	0.675	-2.457
FIN	0.752	0.668	0.653	-13.165
GER	0.727	0.679	0.646	-11.142
ITA	0.759	0.666	0.643	-15.283
JPN	0.589	0.604	0.535	-9.338
KOR	0.694	0.755	0.698	0.720
NLD	0.773	0.672	0.658	-14.877
PRT	0.681	0.653	0.656	-3.671
SVN	n.a.	0.838	0.719	-14.200
SWE	0.768	0.647	0.670	-12.760
UK	0.759	0.702	0.736	-3.030
USA	0.619	0.630	0.603	-2.585

*Labor share measured as (1 – CAP/VA) for code = "TOT"

The overall capital endowment of a country is calculated as the log of total real fixed capital stock over total labor. The overall capital stock consists of different types of capital, whose roles are arguably unique in the production process and can be seen as different production factors. Examining the relationship between structural change and those detailed types of capital endowment will allow us see if the theory's predictions can universally apply to different production factors. Therefore, in addition to the overall capital, the paper examines three detailed categories of capital: ICT, machinery and non-residential structure. However, endowment for these detailed types of capital are more complicated to measure. Although the absolute stocks for all three types of capital have been increasing over time in all countries, their relative importance in the total capital stock has changed considerably.

Figure 2 reports the share changes of each type of capital in total capital stock by country. Notice that ICT capital's importance has risen in all countries while the share of structure capital has almost universally declined. If we consider different types of capital as different

production factors, the endowment measure should take into account both the absolute quantity change in capital-x stock against labor and its relative change against other types of capital as well. Therefore, capital-x endowment is calculated as the log of capital-x stock over total labor multiplied by the share of capital-x (K^x) in the overall capital stock(K) of country j:

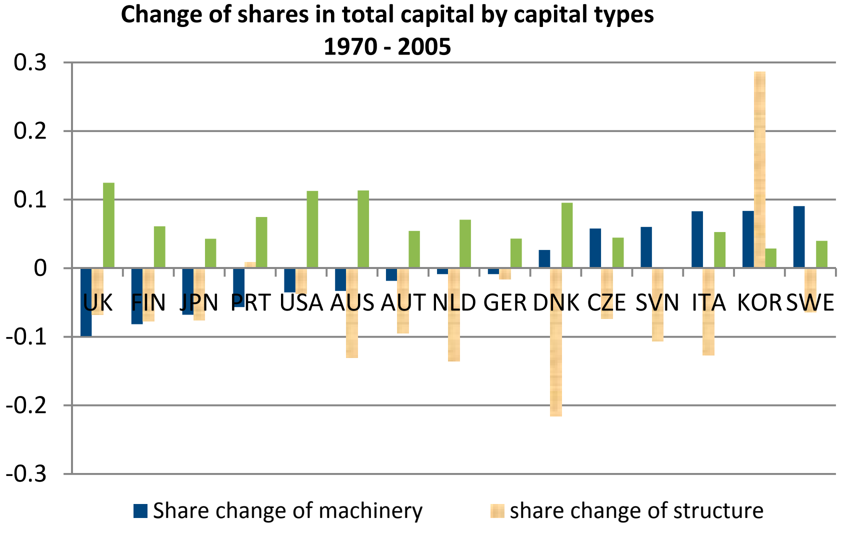
$$\mathrm{K}^x\_\mathrm{ENDW}_{j,t} = \ln\left[\left(\mathrm{K}^x_{jt} / \mathrm{L}_{jt}\right) \times \left(\mathrm{K}^x_{jt} / \mathrm{K}_{jt}\right)\right]$$

According to this definition, the change in capital-x endowment can be expressed as

$$\Delta \mathrm{K}^x\_\mathrm{ENDW} = \frac{\Delta \widetilde{\mathrm{K}}^x}{\widetilde{\mathrm{K}}^x} + \left(\frac{\Delta \widetilde{\mathrm{K}}^x}{\widetilde{\mathrm{K}}^x} - \frac{\Delta \widetilde{\mathrm{K}}}{\widetilde{\mathrm{K}}}\right)$$

where $\widetilde{\mathrm{K}}$ denotes the K / L ratio. In other words, the change in capital-x endowment consists two parts: the percentage change in the value of $\widetilde{\mathrm{K}}^x$ and the difference between the percentage changes of $\widetilde{\mathrm{K}}^x$ and of the overall capital-labor ratio $\widetilde{\mathrm{K}}$.

Figure 2



Industry's capital stock to real output ratio is used as the main measure of capital intensity.[11] For robustness check, the paper also uses capital's income share in industry value-added as an alternative measure. Human capital intensity is used as control variable in some of the regressions, which is measured by high-skill workers' compensation as a percentage of industry's total compensation. Figure 3 plots industry output share-weighted

[11] Some studies also used capital stock over value added ratio as a measure of capital intensity; see for example, Nunn (2007) and Ciccone & Papaioannou (2009). The two measures are highly correlated.

average capital intensities at country level for different types of capital. For all types of capital the average intensities differ across countries. Moreover, at least in some countries, capital intensities are not stationary. This is especially true for ICT capital, the usage of which has experienced surges in all sample countries especially since the 1990s. Even within the same industry, there are often big differences in capital intensity across countries. This difference turns out to be significantly related to the countries' capital endowments. Table 3 presents results of regressing capital intensity on country capital endowment industry by industry for three detailed types of capital. The regression coefficients are positive and highly significant for the majority of industries. There can be different factors causing the positive correlation.

Since the industry classification used here is fairly broad, within the same industry different countries may be specializing in very different sub-industries according to a country's endowment fundamentals. And even when different countries are producing a similar product or service, the techniques they use can differ so as to take advantage of the more abundant factor in the country. The finding is consistent with Blum (2010), who found that a production factor is more intensively used in all industries of a country when the factor becomes more abundant.

Since cross-country differences or time trends in capital intensity is not a focus of this paper, and because correlation between capital endowment and industry capital intensity can potentially cause multicolinearity in the regressions, the standard score of capital intensities instead of the raw capital-output ratio is used in the actual estimations. The standard score is calculated by normalizing an industry's capital-x intensity in country *j* of time *t* with the mean and standard deviation of capital-x intensity of all industries in country *j* at time *t*. The capital intensity score thus has the same distribution within each country and time period, and measures the within-country variations of capital intensity across industries at a point in time.

Figure 3: Capital intensity by country and types of capital

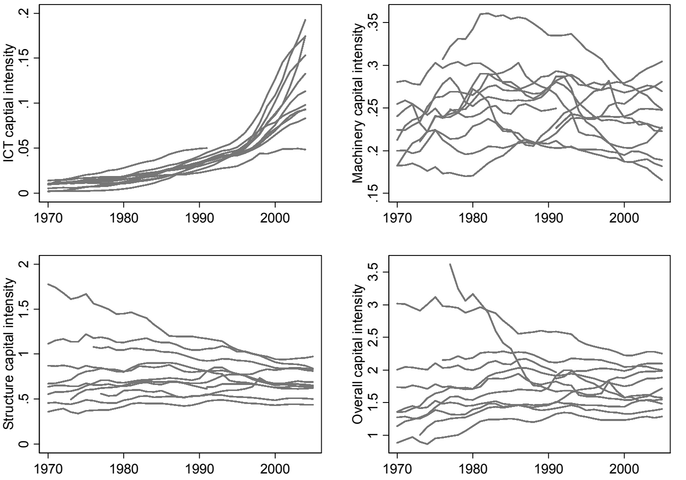


Table 3: Regression of capital intensity on country capital endowment by industry

	ICT capital			Machinery capital			Structure capital		
Industry code	b_1	T value	R square	b_1	T value	R square	b_1	T value	R square
15t16	0.027	24.361	0.620	0.016	9.847	0.210	0.001	6.409	0.101
17t19	0.033	33.991	0.763	0.021	9.634	0.203	0.004	17.080	0.445
20	0.017	6.205	0.096	0.018	5.429	0.075	0.006	14.877	0.378
21t22	0.070	22.206	0.575	0.021	9.006	0.182	0.002	13.503	0.334
23	0.017	5.129	0.068	0.005	0.916	0.002	0.000	0.211	0.000
24	0.033	17.204	0.448	0.001	0.209	0.000	0.002	7.998	0.149
25	0.024	23.064	0.596	0.001	0.218	0.000	0.002	12.078	0.286
26	0.045	22.162	0.575	-0.017	-3.981	0.042	0.002	9.761	0.207
27t28	0.025	28.900	0.696	0.010	3.042	0.025	0.002	8.938	0.180
29	0.049	40.625	0.819	0.032	11.387	0.263	0.002	14.636	0.370
30t33	0.044	21.307	0.555	-0.004	-1.172	0.004	0.000	2.398	0.016
34t35	0.028	23.500	0.603	0.024	4.946	0.063	0.000	0.614	0.001
36t37	0.040	35.584	0.778	0.012	5.748	0.083	0.003	9.307	0.192
50	0.059	27.044	0.668	-0.002	-0.885	0.002	-0.003	-6.507	0.104
51	0.075	31.695	0.734	0.000	0.091	0.000	0.002	5.110	0.067
52	0.076	29.221	0.701	0.010	2.957	0.023	-0.002	-2.739	0.020
60t63	0.080	11.642	0.271	0.000	-0.009	0.000	-0.006	-2.720	0.020
64	0.148	3.893	0.040	-0.003	-0.266	0.000	0.002	1.077	0.003
70	0.029	23.924	0.615	0.002	2.621	0.019	0.044	9.967	0.214
71t74	0.161	20.177	0.528	-0.002	-0.230	0.000	0.059	13.568	0.336
AtB	0.012	9.334	0.195	0.024	2.443	0.016	0.025	14.602	0.369
C	0.058	21.069	0.553	0.003	0.140	0.000	-0.004	-1.881	0.010
E	0.075	15.108	0.385	0.066	4.868	0.061	0.005	1.395	0.005
F	0.018	26.338	0.657	0.004	3.098	0.026	0.001	3.801	0.038
H	0.032	17.229	0.451	0.016	7.737	0.141	0.002	4.612	0.055
J	0.142	29.145	0.700	0.000	0.194	0.000	0.009	11.245	0.258
L	0.105	22.973	0.592	0.029	10.084	0.218	0.027	8.884	0.178
M	0.088	19.100	0.501	0.004	1.633	0.007	-0.002	-1.501	0.006
N	0.054	25.485	0.641	0.000	-0.091	0.000	-0.003	-3.456	0.032
O	0.092	18.291	0.479	0.023	8.084	0.152	-0.007	-4.541	0.054

* The estimation equation is $\text{capital intensity}_{i,j,t} = b_{0,i} + b_{1,i}\text{capital endowment}_{j,t} + e_{i,j,t}$. The equation is estimated for every industry i, and b_1 is the coefficient of capital endowment.

Table 4A: Summary statistics

	# of observations	Mean	Std. Dev.	Min	Max
Country variables					
Overall Capital endowment ($mn)	427	5.001	0.460	3.426	5.989
ICT capital endowment	427	-2.869	2.035	-8.921	1.165
Structure capital endowment	427	3.320	0.673	1.131	4.504
Machinery capital endowment	427	1.159	0.472	-0.488	2.441
Annual growth rate of GDP per worker	416	0.020	0.022	-0.058	0.103
Log GDP per worker ($mn)	427	4.481	0.385	3.353	5.303
Industry variables					
Real output share	11033	0.033	0.023	0.000	0.234
Employment share	11033	0.033	0.028	0.000	0.183
Nominal output share	11033	0.033	0.022	0.000	0.137

* Overall capital endowment of a country is calculated as the log of real overall capital stock over total employment ratio. Endowments of the detailed types of capital are measured as the log of capital-x stock over total employment ratio times the log of capital-x's share in the overall capital stock.

Table 4B: Correlation between country variables

	Capital	GDP	ICT	Structure	Machinery
Overall Capital endowment	1.00				
Log GDP per worker	0.83	1.00			
ICT endowment	0.24	0.42	1.00		

Structure endowment	0.67	0.66	0.11	1.00	
Machinery endowment	0.37	0.68	0.36	0.52	1.00

Table 4C: Correlation between industry variables

	Overall capital	ICT	Structure	Machinery	Human capital	Value-added
Overall capital intensity	1.00					
ICT intensity	0.43	1.00				
Structure intensity	0.81	0.34	1.00			
Machinery intensity	0.19	0.16	0.08	1.00		
Human capital intensity	0.29	0.21	0.20	-0.40	1.00	
Degree of value-added	0.44	0.33	0.49	-0.39	0.45	1.00

* All capital intensities are in standard score form.

Table 4 lists summary statistics of main variables and their correlations. A number of correlations are noteworthy. First, richer countries generally have higher capital endowments. The correlation between per worker GDP and the four catogories of capital are 0.83, 0.42, 0.66 and 0.68 respectively, all significant at 1% level. It raises the question of whether the capital endowment variables are simply stand-in factors for country's development stage. Second, industries that are intensive in overall capital, ICT and structure capital also tend to be human capital intensive. One explanation for the positive correlations may be that the "sophisticated" industries tend to be intensive in multiple types of capital. these questions will be revisited later in the robustness check section.

IV. Country Level Analysis

A. Capital Endowment and Industrial Structure

Before empirically defining and analyzing structural coherence, let's first look at the general patterns in data about the relationship between capital endowment and capital intensity of the industrial structure. One conclusion from Section 2 is that there should be a positive correlation between the two when industry size is calculated as the real output share, since capital-intensive industries grow bigger—in terms of real output-- when capital endowment increases.

When industry shares are calculated in terms of employment or nominal output, the relationship between capital endowment level and capital intensity of the industrial structure depends on ε, the elasticity of substitution between sectors, as the elasticity of substitution determines the magnitude of changes in the relative price corresponding to real output changes. However, in reality several factors can complicate the prediction. First, a real economy has more than two industries and the elasticities of substitution across different industries can be different. Second, as pointed out by Oulton (2001), many industries produce intermediate goods that do not target end consumers, thus making the prediction by elasticity-of-substitution-criteria hard to apply. Third, the countries in the sample are mostly open economies. Hence the domestic demand may have little impact on goods prices, especially for tradable industries in small countries. Although these factors complicate the prediction for the relationship between capital endowment and employment/nominal output share distribution of the industries, at least it should be the case that an industry's

employment share and nominal output share should move in the same direction when endowment changes.

Table 5a and 5b report correlations among endowments in different types of capital and capital intensity of industrial structure in terms of real output, employment and nominal output. The capital intensity of industrial structure is measured in two ways: (1) as $\text{COR}(Y_{ij,t}, K^x_{ij,t})$, the Spearman rank correlation between an industry's capital-x intensity score, K^x_{ij}, and industry size Y_{ij}, which is represented by the real output share, employment share, and nominal output share of the industry in the total economy of country j; (2) as $\sum_{i=1}^{n} K^x_{ij,t} \cdot Y_{ij,t}$, the industry-size-weighted average capital intensity score across all n industries of the economy. From now on, the paper will refer to the two measures as "correlation measure" and "weighted average" measure of the capital intensity of industrial structure.[12] Keep in mind that since K^x_{ij} is the standard score of capital-x intensity, it captures the ranking of capital intensity of industry i relative to other industries within the same country and time period, independent of the average capital intensity of the country. The latter is itself a positive function of the country's capital endowment, as shown in section 3 and in Blum (2010).

The results from Table 5a-b show that for the overall capital, the capital intensity of industrial structure, no matter whether it is calculated in terms of real output, employment, or nominal output shares, is positively correlated with capital endowment level. All the correlation coefficients are significant at 1% level. In terms of magnitude, the correlation coefficient is highest for real output structure, and lowest for the employment structure.

These patterns in the data are present in using both correlation measure (Table 5a) and weighted average measure (Table 5b) for the capital intensity of industrial structure. The capital intensities using all three industry size measures are also positively and significantly correlated. Overall, these results are consistent with the assumption that the elasticity of substitution between industries is generally greater than 1.

Table 5a: Correlation between capital intensity of industrial structure and capital endowment (correlation measure)

	Overall Capital				ICT Capital				Machinery Capital				Structure Capital			
	K^x intensity of real output structure	K^x intensity of employ ment structure	K^x intensity of nominal output structure	Lagged K^x endowm ent	K^x intensity of real output structure	K^x intensity of employ ment structure	K^x intensity of nominal output structure	Lagged K^x endowm ent	K^x intensity of real output structure	K^x intensity of employ ment structure	K^x intensity of nominal output structure	Lagged K^x endowm ent	K^x intensity of real output structure	K^x intensity of employ ment structure	K^x intensity of nominal output structure	Lagged K^x endowm ent
K^x intensity of real output structure	1.00				1.00				1.00				1.00			

[12] The two measures have their respective pros and cons. For example, the weighted average measure captures more variations in capital intensity of industries than the correlation measure, but is sensitive to capital intensity changes in individual industries that can be considered as outliners. Therefore, empirical results using both measures are reported in this paper.

K^x intensity of employment structure	0.54	1.00			0.88	1.00			0.57	1.00			0.68	1.00		
K^x intensity of nominal output structure	0.97	0.59	1.00		0.97	0.88	1.00		0.72	0.60	1.00		0.97	0.71	1.00	
Lagged K^x endowment	0.47	0.27	0.35	1.00	0.45	0.28	0.44	1.00	-0.21	-0.24	-0.30	1.00	0.32	0.07	0.27	1.00

Table 5b: Correlation between capital intensity of industrial structure and capital endowment (weighted average measure)

	Overall Capital				ICT Capital				Machinery Capital				Structure Capital			
	K^x intensity of real output structure	K^x intensity of employment structure	K^x intensity of nominal output structure	Lagged K^x endowment	K^x intensity of real output structure	K^x intensity of employment structure	K^x intensity of nominal output structure	Lagged K^x endowment	K^x intensity of real output structure	K^x intensity of employment structure	K^x intensity of nominal output structure	Lagged K^x endowment	K^x intensity of real output structure	K^x intensity of employment structure	K^x intensity of nominal output structure	Lagged K^x endowment
K^x intensity of real output structure	1.00				1.00				1.00				1.00			
K^x intensity of employment structure	0.45	1.00			0.84	1.00			0.34	1.00			0.60	1.00		
K^x intensity of nominal output structure	0.95	0.54	1.00		0.94	0.81	1.00		0.67	0.52	1.00		0.94	0.71	1.00	
Lagged K^x endowment	0.36	0.12	0.31	1.00	0.55	0.44	0.52	1.00	-0.13	-0.33	-0.30	1.00	0.36	0.12	0.34	1.00

The results for the detailed types of capital are somewhat similar to those for the overall capital. For both ICT and structure capital, capital intensities of industrial structure are positively correlated with capital endowment levels. The correlation coefficients are significant at 1% level except for the correlation between the non-residential structure capital intensity calculated using industry employment shares and the structure capital endowment, which is positive but not significant. In contrast, the correlations between capital intensity of industrial structure and capital endowment are negative for machinery capital, no matter which industry size measure is used.

Despite these exceptions, in general the results from Table 5a-b suggest that the industrial structure tends to be more capital intensive when capital is more abundant. This is, however, a very general description of the data. The countries that have similar levels of capital abundance not necessarily share the same industrial structure in terms of capital intensity. What happens if the capital intensity level of a country's industrial structure is not "coherent" with the level of the country's capital endowment? Does the level of this coherence matter for a country's growth performance? One way to answer these questions is to construct a country-level measure for the degree of coherence between industrial structure and capital endowment, and relate it to economic growth. The next section will implement this approach.

B. Structural Coherence and Growth

The paper uses the term structural coherence to refer to the degree that a country's industrial structure aligns with the country's factor endowment fundamentals. The endowment-based structural change theory predicts that the industrial structure will change towards more capital-intensive industries when the endowment of capital increases, given no distortions to the market system and to individual incentives. However, as Section 2 argues, when adjustment cost associated with structural change is high, the magnitude of structural change will be reduced and the aggregate growth performance negatively impacted. Empirically, previous studies have shown that the characteristics of structural change have aggregate effects on countries' labor market performance (Rogerson, 2007) and on aggregate productivity (van Ark, O'Mahony & Timmer, 2008; Duarte & Restuccia, 2010). But little empirical evidence exists on what kind of industrial structure facilitates growth. This section first proposes a measure for structural coherence at the country level, and then shows that the measure can explain some of the cross-country variation in growth.

Measuring Structural Incoherence at the Country Level

The paper measures structural coherence by its opposite—structural incoherence, that is, the degree that a country's industrial structure deviates from the "optimal" corresponding to the country's capital endowment level. The structural incoherence (SI) index in terms of type-x capital is measured as the absolute gap between the standardized capital-x intensity score of a country's overall industrial structure and the country's capital endowment level, also standardized across countries. In other words, the SI index can be expressed as

$$\mathrm{SI}^{x}_{j,t} = \left| \mathrm{k}^{x}\_\mathrm{inten}_{j,t} - \mathrm{k}^{x}\_\mathrm{endw}_{j,t-1} \right| \quad (14)$$

Here lower-cased letters are used to represent the standard score of the actual variable. Thus the two components of the SI index respectively indicate where a country is in terms of capital intensity of industrial structure and capital endowment, relative to other countries. This measure formulates upon the idea that the capital intensity of the optimal industrial structure should be a strictly increasing function of a country's capital endowment level. Thus in the case of perfect structural coherence, the SI index should be equal to zero; i.e., the level of the industrial structure's capital intensity should be the same as the level of capital endowment, in their respective distributions. Again, to take into account the time lags needed for the industrial structure to adjust to changes in capital endowment, the capital intensity and endowment scores used are those at the ending and beginning years of a 5-year window. Table 6 gives summary statistics of the SI index for the overall capital and three detailed categories of capital. In Version 1 of the SI index, the capital intensity of a country's industrial structure is measured as the rank correlation between industries' real output shares and industries' capital intensities, while in Version 2, it is measured as the industry-real-output-share-weighted average of industry capital intensities. Table 6 shows that the two versions of SI are of similar ranges.

It is illuminating to compare the structural incoherence scores across countries and over time. Figure 4 presents the time trends of the SI score (Version 1) in terms of the overall

capital for 11 sample countries that have relatively long time-series data. A few things are worth noting. Among all countries, Japan has experienced the largest increase in structural incoherence over time, its SI scores close to zero in the 1970s and above 3 in 2005. The SI score has also increased since the 1980s in countries such as Italy and Denmark, though to a less degree. In contrast, countries like US and Germany seem to have consistently lower-than-average SI scores. For US, the score has decreased from the beginning of the sample, and was especially low during the 1990s, a period of extraordinary economic growth for the country. Germany's SI score periodically increased right after the re-unification but decreased again in the late 1990s.

Table 6 Summary statistics of structural incoherence (SI) scores

	Mean	Std. Dev.	Min	Max
SI (version 1):				
Overall capital	0.877	0.541	0.008	3.004
ICT	0.748	0.613	0.007	2.907
Machinery	1.225	0.865	0.015	4.178
Structure	1.004	0.644	0.002	2.908
SI (version 2):				
Overall capital	0.839	0.730	0.001	3.261
ICT	0.674	0.606	0.014	2.525
Machinery	1.186	0.765	0.007	3.869
Structure	1.013	0.599	0.014	3.425

To see which of the two components of the SI score is driving the changes over time, Figure 5 plotted the time trends for the capital intensity of industrial structure (correlation measure) and capital endowment (k_endw_j) separately for each country. The cause for the dynamics in SI score is now clearer. For all sample countries, the capital endowment has increased overtime to various degrees. However, the trend of industrial structure is far less universal. For some countries such as US, Germany, and UK, the capital intensity of industrial structure has risen along with the movement of capital endowment, which results in steady or even decreasing structural incoherence level overtime. For the countries whose SI scores have been increasing, e.g. Japan, Italy, and Denmark, the rise in structural incoherence level is mainly caused by their "sticky" industrial structure, i.e. the lack of upward movement in the overall capital intensity of the industries, despite consistent capital accumulation. Also notice that compared to the US, all the continental European countries except Germany appear to have less responsive industrial structure to the changes in capital endowment. This is consistent with previous studies comparing the characteristics of structural change between US and EU countries. For example, van Ark, O'Mahony & Timmer (2008) show that the slower structural transformation in European countries contributes to the lower labor productivity growth in Europe compared to the United States.

Figure 4: Evolution of structural incoherence score by country

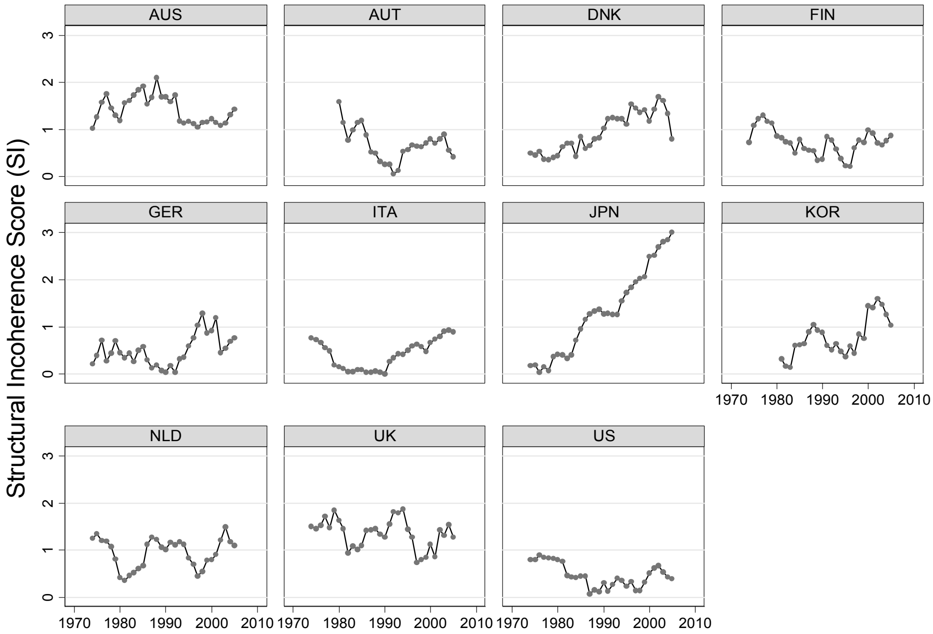
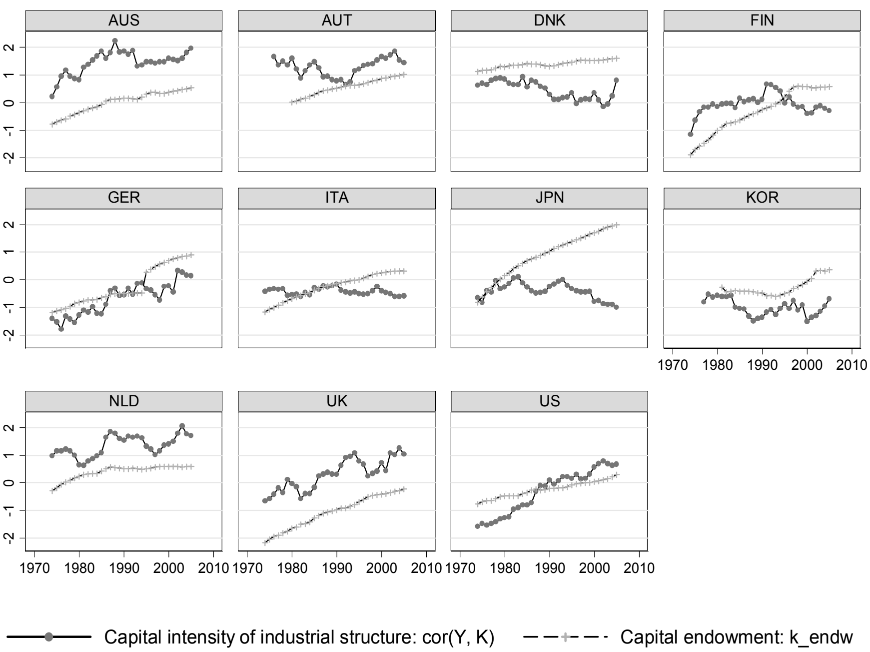


Figure 5: Decomposing the structural incoherence score



Structural Coherence Effect on Growth

The country-level estimation equation for the relationship between structural coherence and growth is

$$\text{GROW}_{j,t-k,t} = b_1 + b_2\left(\frac{1}{k}\sum_{\tau=0}^{k-1}\text{SI}^x_{j,t-\tau}\right) + b_3 Z^{'}_{j,t} + u_{j,t} \qquad (15)$$

where $\text{GROW}_{j,t-k,t}$ is the real GDP growth rate of country j from Year t-k to t. Equation (15) relates aggregate growth rate to the average structural incoherence score over the same period, and a set of control variables Z_j. Here Z_j includes countries' initial GDP at t-k, countries' average physical capital investment intensity, and countries' average human capital intensity as represented by the shares of high skilled and medium skilled workers in total labor compensation. The error term includes country fixed effect and an observation-specific error.

Table 7a and 7b report the results of estimating Equation (15), using the two versions of the SI index respectively. The standard errors are adjusted for heteroskedasticity at the country level. Column 1s of the two tables display results for the overall capital with the annual GDP growth as the dependent variable, i.e. k equals 1. The coefficient b_2 is negative in both versions of regressions, and has a t-statistic of 4.75 and 2.63 respectively. According to the estimate in Version 1, decreasing structural incoherence score from the 75 percentile (1.23) to the 25 percentile (0.46) of the distribution is associated with 0.8 percentage point increase in the annual GDP growth rate, which is about 24% of the growth rate differential between the 25 percentile and 75 percentile country-years.

Column 3 and column 5 Table 7a-b report regression results for the overall capital over 5-year (k=4) and 10-year (k=9) non-overlapping time spans respectively. In both cases, b_2 is negative and significant. In Version 1, the t-statistic of b_2 is equal to 2.15 for the 5-year estimation and 3.42 for the 10-year estimation. In Version 2, the t-statistic is 2.25 and 2.61 for the 5-year and 10-year estimations. To check that the results are not driven by outliers, Figure 6a-c display partial regression plots for the SI variable in Version 1. The three graphs correspond to estimates in Column 1, 3, and 5 of Table 7a respectively. It is clear from the plots that the results are not driven by any particular observations.

Column 2, 4, and 6 of Table 7a and 7b report results for the three detailed types of capital placed in the same regression. For machinery capital, the SI index is negative and significant for all time windows when the capital intensity of industrial structure is calculated as the output-share-weighted industry capital intensity (v2), but is only significant in the annual regression in when the capital intensity of industrial structure is calculated as the rank correlation between industry output share and capital intensity (v1). Structure capital's SI index is mostly negative and significant in both versions of regressions. However, the SI of ICT capital is never significant in any of the regressions.

Regressing GDP growth on contemporaneous SI index raises the possibility of endogeneity. For example, a negative productivity shock can bring down output growth rate, and at the same time mess up the effectiveness of resource allocation in the economy. To take into account such concerns, Equation (15) is also estimated using 2-stage Least Square, with the SI indices of lagged two periods as instruments for the current period SI. The results

are shown in Table 8a-b for the two versions of capital intensity of industrial structure. The results indicate that for the overall capital, the magnitudes of the SI index are comparable to, if not larger than those in the baseline regressions. For the detailed types of capital, the SI coefficients for machinery capital are of the similar magnitudes and significance levels to the baseline results; but for structure capital, the SI index now becomes mostly insignificant.
In sum, the estimates of Equation (15) show that a country's GDP growth is negatively impacted by the degree of incoherence between its industrial structure and its overall capital endowment level. For detailed types of capital, the relationship also exists but is not as clear. However, estimations at the country level do not exploit all the information contained in the data. The next section will adopt a different approach, to examine the relationship between structural coherence and growth based on an industry-level regression setup.

Table 7a Structural coherence and growth: country level regressions (v1)

	Dependent variable: real GDP growth rate					
	k=1		k=4		k=9	
	(1)	(2)	(3)	(4)	(5)	(6)
Structural incoherence index						
Overall capital	-0.010***		-0.042**		-0.149**	
	(0.00)		(0.02)		(0.06)	
ICT		0.004		0.010		0.065
		(0.00)		(0.02)		(0.05)
Machinery (MCH)		-0.004**		-0.017		0.013
		(0.00)		(0.02)		(0.02)
Structure (STR)		-0.005		-0.033*		-0.133**
		(0.00)		(0.02)		(0.05)
Control variables						
High skill	0.001**	0.001**	-0.000	0.006***	-0.015**	0.009*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Medium skill	0.001***	0.001**	0.000	0.005**	0.012**	0.011**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
log(Inv / GDP)	0.019	0.013	0.047	0.023	0.302	0.103
	(0.02)	(0.02)	(0.06)	(0.07)	(0.20)	(0.29)
log(GDP)	-0.025**	-0.033***	-0.222**	-0.178***	-0.275	-0.197
	(0.01)	(0.01)	(0.09)	(0.06)	(0.16)	(0.11)
N	350	350	74	74	29	29
r2	0.076	0.074	0.545	0.283	0.741	0.697

* In constructing SI scores, capital intensity of industrial structure is calculated as the Spearman rank correlation between industry output share and industry capital intensity. Country fixed effect estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. Column 1-2 report annual estimates. Column 3-4 and Column 5-6 report estimates for non-overlapping 5- year and 10-year windows respectively. ***: p<0.01; **: p<0.05; *: p<0.1

Table 7b Structural coherence and growth: country level regressions (v2)

	Dependent variable: real GDP growth rate					
	k=1		k=4		k=9	
	(1)	(2)	(3)	(4)	(5)	(6)
Structural incoherence index						
Overall capital	-0.011***		-0.067**		-0.245***	
	(0.00)		(0.03)		(0.05)	
ICT		-0.000		-0.003		0.020
		(0.00)		(0.02)		(0.07)
Machinery (MCH)		-0.010**		-0.061***		-0.110**
		(0.00)		(0.02)		(0.05)
Structure (STR)		-0.005*		-0.022*		-0.053
		(0.00)		(0.01)		(0.04)
Control variables						
High skill	0.001*	0.002***	0.005	0.009***	-0.000	0.012***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Medium skill	0.001**	0.001**	0.002*	0.005**	0.011***	0.012**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
log(Inv / GDP)	0.014	0.031	0.041	0.114	0.256	0.351

	(1)	(2)	(3)	(4)	(5)	(6)
	(0.02)	(0.02)	(0.08)	(0.09)	(0.22)	(0.26)
log(GDP)	-0.024**	-0.040***	-0.139	-0.221***	-0.012	-0.319***
	(0.01)	(0.01)	(0.08)	(0.05)	(0.11)	(0.08)
N	346	346	72	72	28	28
r2	0.069	0.097	0.292	0.416	0.731	0.703

* In constructing SI scores, capital intensity of industrial structure is calculated as the industry-output-share-weighted industry capital intensity. Country fixed effect estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. Column 1-2 report annual estimates. Column 3-4 and Column 5-6 report estimates for non-overlapping 5- year and 10-year windows respectively. ***: p<0.01; **: p<0.05; *: p<0.1

Table 8a Structural coherence and growth: country level regressions (v1), IV method

	Dependent variable: real GDP growth rate					
	k=1		k=4		k=9	
	(1)	(2)	(3)	(4)	(5)	(6)
Structural incoherence index						
Overall capital	-0.010***		-0.047**		-0.176***	
	(0.00)		(0.02)		(0.04)	
ICT		0.001		0.007		-0.082
		(0.00)		(0.02)		(0.12)
Machinery (MCH)		-0.006**		-0.036**		0.007
		(0.00)		(0.01)		(0.03)
Structure (STR)		-0.005		-0.011		-0.162*
		(0.00)		(0.02)		(0.09)
Control variables						
High skill	0.001**	0.001***	-0.001	-0.002	-0.017***	0.005
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Medium skill	0.001**	0.001**	0.001	-0.000	0.013***	0.015**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
log(Inv / GDP)	0.016	0.013	0.037	-0.002	0.334	0.100
	(0.02)	(0.02)	(0.08)	(0.08)	(0.23)	(0.34)
log(GDP)	-0.033***	-0.042***	-0.217***	-0.280***	-0.245**	-0.213*
	(0.01)	(0.01)	(0.05)	(0.05)	(0.11)	(0.13)
N	326	326	69	69	28	28
r2	0.101	0.106	0.555	0.553	0.735	0.541
Hansen J test (p value)	0.383	0.260	0.510	0.210	0.285	0.660

* The SI scores of lagged two periods are used as instruments for the contemporaneous SI scores. ***: p<0.01; **: p<0.05; *: p<0.1

Table 8b Structural coherence and growth: country level regressions (v2), IV method

	Dependent variable: real GDP growth rate					
	k=1		k=4		k=9	
	(1)	(2)	(3)	(4)	(5)	(6)
Structural incoherence index						
Overall capital	-0.016***		-0.061**		-0.348***	
	(0.00)		(0.03)		(0.05)	
ICT		-0.000		0.013		0.023
		(0.00)		(0.02)		(0.07)
Machinery (MCH)		-0.013***		-0.056***		-0.127***
		(0.00)		(0.02)		(0.04)
Structure (STR)		-0.004		-0.007		-0.045
		(0.00)		(0.02)		(0.04)
Control variables						
High skill	0.001**	0.002***	0.007*	0.010***	-0.004	0.013***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Medium skill	0.001	0.001**	0.002	0.004	0.013***	0.013**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
log(Inv / GDP)	0.011	0.032**	0.040	0.138	0.288	0.437
	(0.02)	(0.02)	(0.10)	(0.12)	(0.27)	(0.27)
log(GDP)	-0.032***	-0.051***	-0.185***	-0.247***	0.104	-0.326***
	(0.01)	(0.01)	(0.07)	(0.05)	(0.07)	(0.07)
N	320	320	66	66	27	27
r2	0.109	0.136	0.347	0.451	0.671	0.700
Hansen J test (p value)	0.844	0.312	0.586	0.841	0.861	0.213

* The SI scores of lagged two periods are used as instruments for the contemporaneous SI scores. ***: p<0.01; **: p<0.05; *: p<0.1

Figure 6a: GDP growth and structural incoherence (annual)

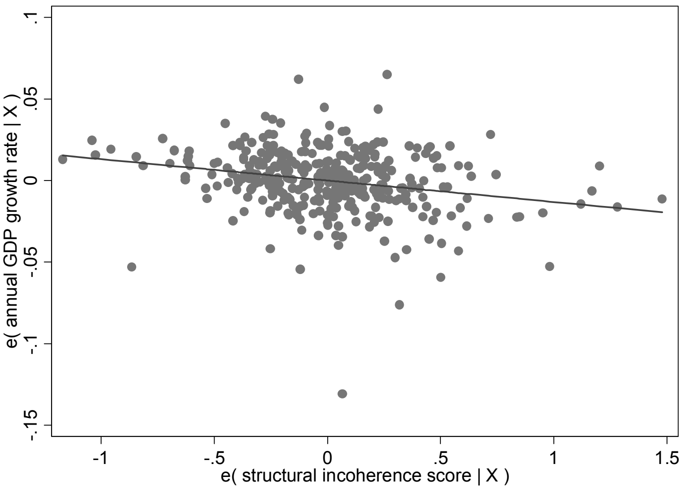


Figure 6b: GDP growth and structural incoherence (5-year window)

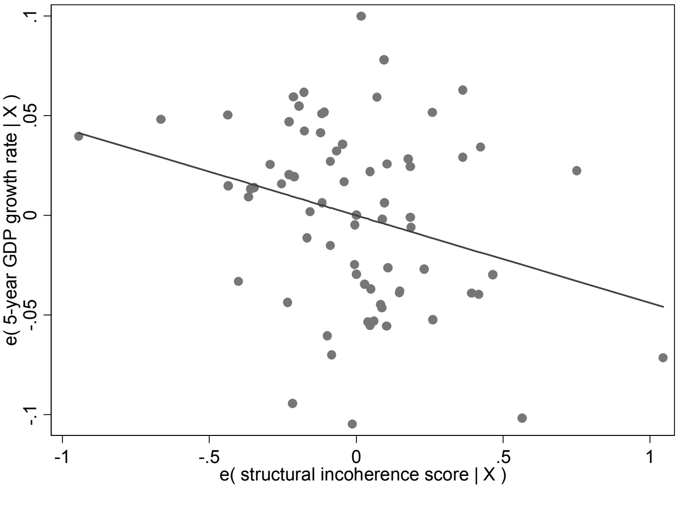
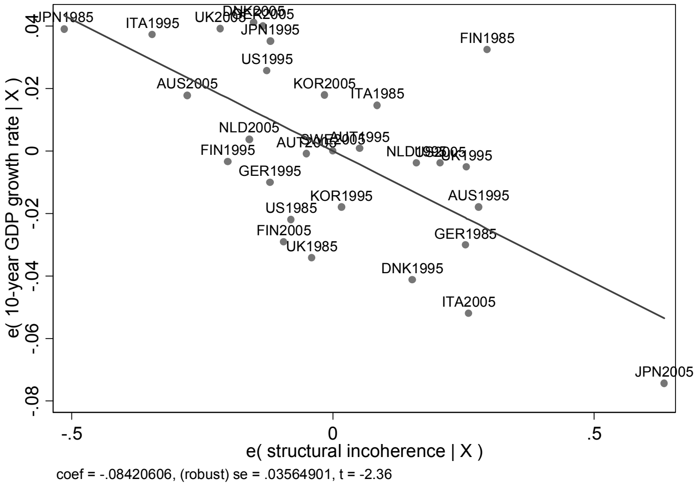


Figure 6c: GDP growth and structural incoherence (10-year window)



V. INDUSTRY LEVEL ANALYSIS

A. Capital Endowment and Industrial Structure

This section examines the relationship between capital endowment and industrial structure using individual industries' data. Again, to allow for the slow adjustment in the industrial structure, the time unit is set to be 5 years. The basic estimation equation is as follows

$$\ln Y_{ij,t} = a_1 + a_2 \mathrm{K}^x_{ij,t-1} + a_3(\mathrm{K}^x_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1}) + a_5 \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} + a_7 Z'_{ijt} + a_8 \ln Y_{ij,t-1} + e_{ijt} \tag{16}$$

where the dependent variable is the log of real output share, employment share, or nominal output share of industry *i* in country *j* in the last year of a 5-year window; $\mathrm{K}^x_{ij,t-1}$ is the standardized capital-x intensity of industry *i* in country *j* at the beginning year of the 5-year window; $\mathrm{K}^x\_\mathrm{ENDW}_{j,t-1}$ is the capital-x endowment in country j in the same year.

Equation (16) does not account for the possibility that contemporaneous growth in capital endowment can also impact industrial structure. To allow for the endowment growth effect, Equation (16) is augmented by adding country-level capital endowment growth over the 5-year period and its interaction with initial-year industry capital intensity:

$$\ln Y_{ij,t} = a_1 + a_2 \mathrm{K}^x_{ij,t-1} + a_3(\mathrm{K}^x_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1}) + a_4(\mathrm{K}^x_{ij,t-1} \times \Delta\mathrm{K}^x\_\mathrm{ENDW}_{j,t}) + a_5 \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} + a_6 \Delta\mathrm{K}^x\_\mathrm{ENDW}^t_{j,t} + a_7 Z'_{ijt} + a_8 \ln Y_{ij,t-1} + e_{ijt} \tag{17}$$

where $\Delta K^x\_ENDW_{j,t}$ is the 5-year growth rate of capital-x endowment in country *j*. In both equations, Z'_{ijt} is a vector of control variables, which includes country *j*'s log per worker aggregate output at the beginning year and the 5-year growth rate of industry TFP index. To control for the initial difference in the dependent variable, $\ln Y_{ij,t-1}$ is also included on the right hand side. The error term consists of a country-industry fixed effect and an observation specific error: $e_{ijt} = u_{ij} + \varepsilon_{ijt}$.

According to Equations (16) and (17), the capital-x endowment effect and endowment growth effect on the dependent variable $\ln Y_{ij}$ are respectively

$$\frac{\partial \ln Y_{ij,t}}{\partial K\_ENDW_{j,t-1}} = a_3 K^x_{ij,t-1} + a_5, \text{ and } \frac{\partial \ln Y_{ij,t}}{\partial \Delta K\_ENDW_{j,t}} = a_4 K^x_{ij,t-1} + a_6 \qquad (18)$$

Both terms are linear functions of $K^x_{ij,t-1}$, the capital-x intensity score of industry *i*. When capital-x endowment is higher, ideally the industries that use capital-x intensively (industries with high K^x_{ij}) should expand in terms of real output. Therefore, when Y_{ij} is the real output share of industry, a_3 and a_4 are expected to be positive. The intercepts a_5 and a_6 help determine the magnitudes of the capital endowment effects on $\ln Y_{ij}$. When Y_{ij} is the employment share or nominal output share, a_3 and a_4 would be positive if the elasticity of substitution between different industrial goods is greater than 1, vice versa.

Again, by standardizing capital intensities, the paper makes sure that the intercepts of the endowment effect, a_5 and a_6 are invariant with respect to the level of capital endowment,[13] and that the endowment effect on industrial structure measured here is separate from any structural change effect caused by endowment-change-induced technology shift.

The error term in Equations (16) and (17) involves country-industry fixed effects that may co-vary with the dependent variables. The inclusion of lagged dependent variables on the RHS creates correlation between the regressors and the error term, which renders OLS estimation inconsistent. Therefore, the paper uses Arellano – Bond (1991) difference GMM method to estimate the model. One thing to keep in mind is that the structural change patterns are different across countries and time periods. Ideally Equations (16) and (17) can be estimated for each country and time period separately. This is not achievable due to data limitations and identification problems. By estimating the model in a cross section-time

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[13] Suppose that instead of a standard score, the raw capital intensity $\widetilde{k_{ij}}$, which is a function of capital endowment in country *j*, is used in the estimation. The endowment effect on Y_{ij} is thus: $\partial \ln Y_{ij} / \partial K\_ENDW_j = (a_2 + a_3)\partial \widetilde{k_{ij}} / \partial K\_ENDW_j + a_3 + a_3 \widetilde{k_{ij}}$. The intercept term $(a_2 + a_3)\partial \widetilde{k_{ij}} / \partial K\_ENDW_j + a_3$ is not constant unless $\partial \widetilde{k_{ij}} / \partial K\_ENDW_j$ is invariant with respect to K_ENDW.

series setting, we get coefficients describing general patterns in the whole data set, which might be quite different than what is going on in a specific country and time. In fact, the assumption that the coefficients for the interaction terms vary across country and time is the basis to test the relationship between structural coherence and growth, which will be specified in Section 5.2.

Table 8 reports the regression results of Equations (16) and (17) for the overall capital. Heteroskedasticity-robust standard errors are reported in the parentheses. The main variables of interest are the interaction term between industry capital intensity (K) and initial capital endowment (K_ENDW) and the interaction between capital intensity and endowment growth (ΔK_ENDW). The 2nd column under each explanatory variable heading reports the results of Equation (16), and the 3rd column of Equation (17), both using Arellano – Bond estimator. For comparison, Equation (16) is also estimated using fixed effect estimator, which is reported in the 1st column under each dependent variable heading.

For all the three industry size regressions, the coefficients of capital endowment interaction are positive and significant, except in the 3rd employment share regression. The coefficients of the endowment growth interaction are also positive and mostly significant. The result thus suggests that the sizes of capital-intensive industries' real output, nominal output and employment all grow with higher capital endowment and capital accumulation. These results are also consistent with the assumption of the elasticity of substitution across different industries being higher than one. Comparing the two estimation methods, the estimated a_3 is lower using the GMM estimator in the real output and employment shares regressions, while higher in the nominal output regression. The coefficient for industry TFP growth is positive and significant in the real output share regression, indicating that industrial structure generally shifts towards industries with higher TFP, consistent with the prediction of Ngai & Pissarides (2007).

Table 8 also reports the results of Arellano – Bond 2nd order serial correlation test and Hansen J test of overidentification for the GMM estimates. All test scores are satisfactory, indicating that the instrument specification is basically sound.[14]

Table 8: Overall capital and structural change: baseline estimation

	Dependent variable: log (Real output share)			log(Employment share)			log(Nominal output share)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	Fixed effect	GMM	GMM	Fixed effect	GMM	GMM	Fixed effect	GMM	GMM
K × K_ENDW	0.135**	0.033*	0.041*	0.132**	0.058**	0.005	0.127*	0.145***	0.190***
	(0.063)	(0.02)	(0.02)	(0.062)	(0.03)	(0.01)	(0.071)	(0.05)	(0.06)

[14] The Hansen J test is weakened by too many instruments, which can lead to improbably good p values of 1 or close to 1. Thus in estimating the model, I either limit the instruments used to up to two lags of the instrumented variable, or collapse longer lags of instruments into smaller set; the 2nd method makes the instrument count linear in the total time periods (Roodman, 2008).

K ×Δ K_ENDW			0.043			0.071**			0.531***
			(0.04)			(0.03)			(0.13)
K_ENDW	0.014	0.003	0.006	-0.124	0.053**	-0.004	-0.035	0.042	0.040
	(0.111)	(0.02)	(0.02)	(0.121)	(0.02)	(0.01)	(0.121)	(0.05)	(0.06)
Δ K_ENDW			-0.006			-0.009			0.153*
			(0.03)			(0.03)			(0.08)
TFP growth	0.007***	0.001	0.001	-0.009***	-0.001***	-0.000	-0.001	0.000	0.001
	(0.002)	(0.00)	(0.00)	(0.002)	(0.00)	(0.00)	(0.002)	(0.00)	(0.00)
N	8959	8527	8527	8959	8527	8527	8959	8527	8527
R2	0.22			0.20			0.06		
A-B 2 test (p value)		0.692	0.688		0.357	0.108		0.241	0.731
Hansen J test (p value)		0.122	0.421		0.889	0.646		0.247	0.165

* The fixed-effect estimates are reported in the 1st column under each dependent variable heading. The Arellano-Bond difference GMM estimates are reported in Column 2-3 under each dependent variable heading. Heteroskedasticity-robust standard errors are in the parentheses. K is the overall capital intensity. K_ENDW is overall capital endowment. ΔK_ENDW is the 5-year growth rate of overall capital endowment. Lagged dependent variables and country's real aggregate output per worker are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

Table 9 reports estimates of Equation (16) and (17) when K^x s are the intensities in detailed types of capital. Compared to the results for the overall capital, the relationships between detailed types of capital endowment and structural change are more ambiguous. In all three industry size regressions, the two interaction terms for ICT capital are positive and significant, while the magnitude of the coefficients is generally greater in the nominal and real output share regressions than in the employment share regression. For structure capital, the interaction terms are also mostly positive, but are only significant in the employment share regression when the GMM estimator is used. For machinery capital, however, the interaction terms are mainly negative, while the significance levels of the coefficients vary.

All in all, echoing the results at the country level, when detailed categories of capital are treated as separate production factors, the results only partially confirm the theoretical prediction about the relationship between factor endowment and industry size. Thus the next section will examine whether these deviations from the theoretical optimal industrial structure have any effect on economic growth, based on the industry-level regression setup.

Table 9: Detailed types of capital and structural change: baseline estimation

	Dependent variable:								
	log (Real output share)			log(Employment share)			log(Nominal output share)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	Fixed effect	GMM	GMM	Fixed effect	GMM	GMM	Fixed effect	GMM	GMM
ICT × ICT_ENDW	0.044***	0.031***	0.023***	0.044***	0.005**	0.009**	0.044***	0.044***	0.042***
	(0.006)	(0.01)	(0.00)	(0.006)	(0.00)	(0.00)	(0.006)	(0.01)	(0.01)
STR × STR_ ENDW	0.057	0.002	-0.007	0.057	0.021*	0.039***	0.057	0.045	0.059
	(0.036)	(0.03)	(0.02)	(0.036)	(0.01)	(0.01)	(0.036)	(0.05)	(0.04)
MCH × MCH_ ENDW	0.016	-0.036	-0.024	0.016	-0.028***	-0.055***	0.016	-0.087***	-0.129***
	(0.024)	(0.03)	(0.02)	(0.024)	(0.01)	(0.02)	(0.024)	(0.03)	(0.03)
ICT ×Δ ICT_ENDW			0.029**			0.019**			0.046*
			(0.01)			(0.01)			(0.03)
STR ×Δ STR_ENDW			0.013			0.065**			0.083
			(0.04)			(0.03)			(0.08)

MCH ×Δ MCH_ENDW			-0.068			-0.082***			-0.162**
			(0.04)			(0.03)			(0.07)
TFP growth	0.005***	0.002	-0.001	0.005***	-0.000	-0.002	0.005***	-0.004**	-0.004**
	(0.001)	(0.00)	(0.00)	(0.001)	(0.00)	(0.00)	(0.001)	(0.00)	(0.00)
N	8934	8502	8502	8934	8502	8502	8934	8502	8502
R2	0.40			0.40			0.40		
A-B 2 test (p value)		0.292	0.895		0.125	0.158		0.822	0.512
Hansen J test (p value)		0.244	0.277		0.186	0.253		0.326	0.837

* The fixed-effect estimates are reported in the 1st column under each dependent variable heading. The Arellano-Bond difference GMM estimates are reported in Column 2-3 under each dependent variable heading. Heteroskedasticity-robust standard errors are in the parentheses. ICT, STR and MCH are capital intensities in information technology, structure and machinery capital. K^x _ENDW is capital-x endowment. ΔK^x _ENDW is the 5-year growth rate of capital-x endowment. Lagged dependent variables and country's real aggregate output per worker are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

B. Structural Coherence and Economic Growth

Recall that in Equation (16), a_3 is the coefficient for the interaction term between industry capital-x intensity and country's capital-x endowment: "$K^x_{ij,t-1} \times K^x\_ENDW_{j,t-1}$", which is expected to be positive when the dependent variable is the real output share and the industrial structure is optimally chosen. Ideally, Equation (16) can be estimated by each country and time period. The value $a_{3,j,t}$ would give a measure of the coherence level between country *j*'s industrial structure and its capital-x endowment level at time *t*. Suppose that a_3^* is the value of $a_{3,j,t}$ when the industrial structure optimally reflects the endowment level. Since frictions and adjustment costs are almost inevitable that obstruct optimal resource allocation and the evolution of industrial structure, this theoretical optimal a_3^* is not very likely to be reached in a real economy. When the sizes of industries are prevented from evolving with capital accumulation, $a_{3,j,t}$ will be less than a_3^*. Moreover, the smaller $a_{3,j,t}$ is, the less adaptive the industrial structure is to endowment change. In the extreme case when industrial structure change is to the opposite direction of capital endowment change, $a_{3,j,t}$ would be negative. The aggregate growth rate of country *j*, "GROW_j", can be modeled as a function of $a_{3,j}$. The paper assumes that this relationship is linear and can be expressed as

$$\mathrm{GROW}_j = f_1 + f_2 a_{3,j} \qquad (19)$$

A high $a_{3,j}$ suggests that the industrial structure is more coherent with endowment level. If the coherence level between industrial structure and capital endowment have a positive impact on a country's growth performance, then f_2 is expected to be positive.

There are obviously important caveats to this functional form. First, it assumes that frictions in the real economy make it costly to adjust resource allocation across industries, as specified in the theoretical model, which generally make industrial structure "sticky", i.e., prevent industrial structure from evolving to reflect endowment change, thus lead to $a_{3,j}$ being lower than a_3^*. But the opposite is also possible. Centralized economic policies by

countries such as the former Soviet Union push for rapid industrialization and force the capital-intensive industries to expand too quickly despite the country's low capital endowment, which led to poor growth performance. In that case $a_{3,j}$ can be higher than the optimal value a_3^*. This extreme case is not captured by assuming a simple linear relationship between growth and $a_{3,j}$. However, most countries covered in the sample are fairly developed, free market economies. No historical records indicate that forced industrialization has been part of the economic policies in these countries over the sample period. Thus the paper assumes it is reasonably safe to neglect the case of overly high $a_{3,j}$ in this sample.[15]

Second, the relationship between economic growth and structural coherence specified in Equation (19) does not necessarily hold for every single period. Economies experience business cycle fluctuations regularly for non-structural reasons. Besides, the goal of the optimizing agents is not high growth for any single period, but life-time welfare maximization. Despite these qualifications, f_2 should be positive if the observations are over an extended period of time, since Equation (19) means to capture the long-run relationship between growth and structural coherence.

Due to limited variation in "K_ENDW" and the small number of observations per country in each period, $a_{3,j,t}$ can hardly be identified by estimating Equation (16) by country and time. But the identification of f_2 is still achievable. Writing Equation (19) as a function of $a_{3,j,t}$ and plugging it back to Equation (16) with the real output share as the dependent variable, we arrive at the following specification:

$$\begin{aligned}\ln Y_{ij,t} &= d_1 + d_2 \mathrm{K}^x{}_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \times \mathrm{GROW}_{j,t} + d_3 \mathrm{K}^x{}_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} + d_4 \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \times \mathrm{GROW}_{j,t} \\ &+ d_5 \mathrm{K}^x{}_{ij,t-1} \times \mathrm{GROW}_{j,t} + d_6 \mathrm{K}^x{}_{ij,t-1} + d_7 \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} + d_8 \mathrm{GROW}_{j,t} + d_9 \mathrm{Z}'_{ijt} + d_{10} \ln Y_{ij,t-1} + \zeta_{ijt}\end{aligned} \tag{20}$$

where $\ln Y_{ij,t}$ is the real output share of industry *i* in country *j*, $\mathrm{GROW}_{j,t}$ is country *j*'s GDP growth rate over the 5-year window. The terms "$\mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \times \mathrm{GROW}_{j,t}$", "$\mathrm{K}^x{}_{ij,t-1} \times \mathrm{GROW}_{j,t}$", and "$\mathrm{GROW}_{j,t}$" are added to the regression equation to maintain the statistical balance of the model.

[15] As a robustness check, I also ran the same regressions leaving out data from Czech Republic and Slovenia, two former satellite countries of the Soviet Union. The results did not change very much. Due to space limit, those results are not reported in the paper.

The coefficient a_3 in Equation (16) is the counterpart of "$d_2 \text{GROW}_{j,t} + d_3$" in Equation (20). According to our hypothesis, the coefficient d_2, which is equal to $1/f_2$, is expected to be positive.

The estimation results of Equation (20) are reported in Table 10 for the overall capital and the three detailed types of capital. The 1st column under each capital type heading estimated Equation (20) using OLS with country fixed effects, the 2nd column under each heading reports results using dynamic GMM estimator. The three-way interaction terms "$K^x_{ij,t-1} \times K^x\_\text{ENDW}_{j,t-1} \times \text{GROW}_{j,t}$" are positive and significant at 1% level for all categories of capital except for the non-residential structure capital when the fixed-effect estimator is used. Therefore, the results generally confirm the hypothesis of a positive relationship between structural coherence and economic growth. The 2nd order serial correlation test and overidentification test results are mostly satisfactory, except for structure capital. The Hansen's J test score of the structure capital regression is exceptionally high, indicating that the score may be weakened by instrument proliferation.

To get a sense of the magnitude of structural coherence's influence on growth, let's look at the results for the overall capital as an example. Notice that $d_2 = 0.242$ (the 2nd column) implies the value of f_2 around 4.13. Suppose that we take the estimate for a_3, the coefficient for the interaction term "K × K_ENDW" in Equation (16) (the 2nd column of Table 8) to be the optimal value a_3^* when industrial structure is fully in line with overall capital endowment. This is most likely an under-estimate of the "true" a_3^* due to various frictions in the real economies. The estimates of Equation (16) and (20) combined indicate a difference in 5-year aggregate output growth rate of 0.136 between the case of highest structural coherence and the case when structural change happens randomly, in which scenario a_3 is equal to zero. Calculated this way, the growth differential related to structural coherence is about 25% of the gap between the growth rate of the 5 percentile and the 95 percentile countries in the data. Although calculated using different approaches, the country-level and industry-level estimates give surprisingly consistent assessments about the magnitude of structural coherence's impact on growth. The consistency provides additional confirmation to the estimation results.

Table 10: Structural coherence and economic growth: baseline estimates

	Dependent variable: log(real output share)							
	Overall capital		ICT		Structure		Machinery	
	(1) Fixed effect	(2) GMM	(1) Fixed effect	(2) GMM	(1) Fixed effect	(2) GMM	(1) Fixed effect	(2) GMM
K ×K_ENDW × GROW	0.231***	0.242***						
	(0.078)	(0.09)						
ICT × ICT_ENDW × GROW			0.118**	0.023**				
			(0.060)	(0.01)				
STR × STR_ENDW × GROW					0.094	0.060**		
					(0.121)	(0.03)		

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MCH×MCH_ENDW×GROW							0.385**	0.333***
							(0.190)	(0.13)
K × K_ENDW	0.070***	-0.035						
	(0.020)	(0.03)						
ICT × ICT_ENDW			0.042***	0.005***				
			(0.008)	(0.00)				
STR × STR_ENDW					0.079*	0.017		
					(0.043)	(0.01)		
MCH × MCH_ENDW							-0.009	-0.038
							(0.035)	(0.03)
N	8959	8527	8934	8502	8964	8532	8964	8532
r2	0.25		0.34		0.30		0.20	
A-B 2 test (p value)		0.740		0.729		0.728		0.378
Hansen J test (p value)		0.296		0.288		0.997		0.328

* The dependent variable is the log real output share of industry. Column 1-2 reports estimates for K^x = overall capital; columan 3-8 report results for K^x = ICT, structural and machinery capital respectively. K, ICT, STR and MCH are capital intensities in overall, information technology, structure and machinery capital. K^x _ENDW is capital-x endowment. GROW is the 5-year average aggregate real output growth rate of a country. Fixed-effect estimates are reported in the odd-numbered columns, and Arellano-Bond difference GMM estimates in even-numbered columns. Heteroskedasticity-robust standard errors are in the parentheses. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

VI. Robustness

A. Using income share to measure factor intensity

In the baseline regressions the ratio of industry capital-x stock to real output is used as the measure of industry capital-x intensity. To see how sensitive the main results are to the choice of measurement, here capital income share in industry value added is used as an alternative measure of capital intensity. In Table 11 and 12, the variables in lowercase letters -- k, ict, str, mch – stand for factor intensity scores in overall, ICT, structure and machinery capital, calculated as standardized capital income shares in industry value added.

Table 11 reports the regression results of Equation (17) with the alternative measure. Compared to the results in Table 8 for the overall capital, the coefficients for the initial endowment interaction becomes insignificant in all regressions, while the significance level for the endowment growth interaction term mostly increase except in the employment share regression. Among detailed types of capital, the two interaction terms for the structure capital become more significant in the nominal output size regression. Most of the other coefficients remain the same sign and significance level. The specification test results are all satisfactory except for the 2nd order serial correlation test in the nominal output size regression involving the overall capital.

Table 11: Capital endowments and structural change: alternative measure of capital intensity

	Dependent variable:					
	Log (real output share)		Log (employment share)		Log (nominal output share)	
	(1)	(2)	(1)	(2)	(1)	(2)
k × K_ENDW	0.055		-0.029		0.028	
	(0.08)		(0.04)		(0.05)	

k ×Δ K_ENDW	0.391**		-0.040		0.296*	
	(0.16)		(0.11)		(0.17)	
ict × ICT_ENDW		0.013***		0.017***		0.026***
		(0.00)		(0.01)		(0.01)
str × STR_ ENDW		0.006		0.034**		0.032**
		(0.01)		(0.01)		(0.01)
mch × MCH_ ENDW		-0.019		-0.108***		-0.243***
		(0.01)		(0.03)		(0.05)
ict ×Δ ICT_ENDW		0.028***		-0.020		0.094***
		(0.01)		(0.02)		(0.02)
str ×Δ STR_ENDW		0.017		0.137		0.060
		(0.03)		(0.09)		(0.07)
mch ×Δ MCH_ENDW		-0.002		-0.077		-0.289***
		(0.03)		(0.06)		(0.10)
TFP growth	0.004***	0.001	0.000	-0.008***	0.001**	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
N	8019	7321	8019	7321	8019	7321
A-B 2 test (p value)	0.541	0.925	0.156	0.921	0.002	0.175
Hansen J test (p value)	0.762	0.182	0.122	0.152	0.229	0.898

* The Arellano-Bond difference GMM estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. k, ict, str and mch are capital intensities in overall, information technology, structure and machinery capital, which are measured as capital-x income share in industry value-added. K^x _ENDW is capital-x endowment. ΔK^x _ENDW is the 5-year growth rate of capital-x endowment. Lagged dependent variables and country's real aggregate output per worker are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

For the structural coherence and growth regression (Equation (20)), as shown in Table 12, the three-way interaction terms are positive and significant for all types of capital except for non-residential structure. Compared to the baseline regression, the magnitude of the implied value of f_2 is now smaller for the overall capital and ICT capital, and larger for the machinery capital. All in all, changing the measure of capital intensity does not seem to significantly change the regression results.

Table 12: Structural coherence and economic growth: alternative measure of capital intensity

	Dependent variable: log(real output share)			
	Overall capital	ICT	Structure	Machinery
k ×K_ENDW × GROW	0.610*			
	(0.34)			
ict × ICT_ENDW × GROW		0.037**		
		(0.02)		
str × STR_ENDW × GROW			-0.011	
			(0.04)	
mch × MCH_ENDW × GROW				0.191**
				(0.09)
k × K_ENDW	-0.008			
	(0.06)			
ict × ICT_ENDW		0.014***		
		(0.00)		
str × STR_ENDW			0.005	
			(0.01)	

mch × MCH_ENDW				-0.024
				(0.03)
N	8961	8297	7350	8210
A-B 2 test (p value)	0.926	0.773	0.783	0.846
Hansen J test (p value)	0.882	0.144	0.464	0.546

* The dependent variable is the log real output share of industry. Column 1 reports estimates for K^x = overall capital; columan 2-4 report results for K^x = ICT, structural and machinery capital respectively. Capital-x intensity is measured by capital-x's income as a share in industry value added. k, ict, str and mch are capital intensities in overall, information technology, structure and machinery capital. K^x _ENDW is capital-x endowment. GROW is the 5-year average aggregate real output growth rate of a country. The Arellano-Bond difference GMM estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

B. Further Robustness Checks

The results presented so far have not considered a range of other factors affecting the structural change process besides capital endowment and TFP growth. This section aims to address several of these factors. First, it is important to make sure that capital intensities are not stand-in variables for other industry characteristics that would impact industry growth when interacting with capital endowment. One such characteristic is human capital intensity. Ciccone & Papaioannou (2009) found that human capital intensive industries grow faster as human capital accumulates.[16] Table 3C has shown that industry human capital intensity has significant positive correlation with overall, ICT and structure capital intensities.

Meanwhile, more developed countries may have high endowments in both human capital and various types of physical capital. Therefore, Equation (17) is augmented with human capital intensity and the interactions between human capital intensity and different types of physical capital endowment.

It is also possible that capital endowments proxy for other influential variables such as economic development level. The demand-side literature on structural change motivates shifts in industrial composition by assuming non-homothetic consumer preferences: as a country becomes richer, consumer preference shifts to services and other more "sophisticated" goods (e.g., Echevarris (1997), Laitner (2000), Buera & Kaboski (2009)). If this is true, then since capital-intensive industries generally involve relatively complicated technology and production process, it is possible that those industries grow more in high-income countries due to demand side reasons, and capital endowment level can simply be a substitute for the effect of national income. Similarly, it is possible that rich countries have an advantage in high value-added industries. If those industries happen to be capital intensive, then our previous results can be generated for completely different reasons. To account for these possibilities, additional controls are added to Equation (17), including the interactions between industry capital intensities and countries' aggregate output per worker of the same period, and also the interaction between industries' degree of value-added (value-added to industry gross output ratio) and countries' aggregate output per worker.

[16] I also estimated Equation (17) for human capital endowment. The result is similar to Ciccone & Papaioannou (2009). Due to space limit, the results are not reported.

Table 13 reports the regression results of Equation (17) for the overall capital, augmented with the above controls. The 1st column under each dependent variable heading is the result when human capital intensity (HUM) and its interaction with overall capital endowment (HUM × K_ENDW) are added to the model. The coefficients for the human capital interaction terms are all positive and significant in the three industry size regressions. Adding human capital controls increases the significance level of the initial capital endowment interaction "K × K_ENDW" in the employment share regression, and of the capital endowment growth interaction "K × ΔK_ENDW" in the real output share regression. However, the initial endowment interaction now becomes insignificant in the real output share regression.

The 2nd column under each explanatory heading reports results with controls of countries' GDP per worker (Y) and industries' degree of value-added (HighVA). While none of the coefficients for the interaction term "K × Y" is significant, the coefficients for the interaction term "HighVA × Y" are positive in all three industry size regressions, and significant in two of them. These results indicate that high value-added industries are indeed larger in higher-income countries. The main interaction terms "K × K_ENDW" and "K × ΔK_ENDW" remain the same signs and significance levels as before, except that the initial endowment interaction "K × K_ENDW" is now insignificant in the real output share regression and is more significant in the employment share regression. The results in the nominal output share regressions should be treated with caution, as the serial correlation test results are not satisfactory, which makes the use of lagged dependent variable as instruments questionable.

Table 13: Overall capital endowment and structural change: additional controls

	Dependent variable:					
	Log (real output share)		Log (employment share)		Log (nominal output share)	
	(1)	(2)	(1)	(2)	(1)	(2)
K × K_ENDW	0.025	0.062	0.040**	0.039*	0.072*	0.081*
	(0.03)	(0.05)	(0.02)	(0.02)	(0.04)	(0.05)
K ×Δ K_ENDW	0.117**	0.111	0.095**	0.133**	0.206***	0.242***
	(0.06)	(0.09)	(0.04)	(0.05)	(0.07)	(0.09)
HUM × K_ENDW	0.070***		0.035***		0.184***	
	(0.02)		(0.01)		(0.03)	
K × Y		-0.003		0.007		-0.075
		(0.03)		(0.01)		(0.07)
HighVA × Y		1.103***		0.095		0.797***
		(0.19)		(0.09)		(0.25)
N	8419	8527	8419	8527	8419	8527
A-B 2 test (p value)	0.745	0.961	0.102	0.115	0.005	0.032
Hansen J test (p value)	0.154	0.366	0.224	0.206	0.235	0.141

* The Arellano-Bond difference GMM estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. K and HUM are capital intensities in overall fixed capital and human capital. HighVA is the ratio of industry value-added over gross output. K_ENDW is overall capital endowment. ΔK_ENDW is the 5-year growth rate of overall capital endowment. Y is country's aggregate real output per worker. Lagged dependent variables, country's real aggregate output per worker, and industry TFP growth index are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

Table 14 reports estimates of Equation (17) for the detailed capitals with additional controls. The interaction terms involving human capital intensity are not significant except for the interaction between human capital intensity and ICT endowment in the employment share regression. The interactions between capital intensity and country GDP level are only

significant for machinery capital intensity in the employment and nominal output share regressions. The interaction between industries' degree of value added and country GDP is positive in all regressions, but not significant. Compared to the baseline estimates, the main interaction terms lost significance to some extent, especially for structure capital. But the signs of the coefficients remain the same, except for machinery capital, whose interactions changed signs when country GDP related controls are added.

Table 14: Detailed capital endowments and structural change: additional controls

	Dependent variable:					
	Log (real output share)		Log (employment share)		Log (nominal output share)	
	(1)	(2)	(1)	(2)	(1)	(2)
ICT × ICT_ENDW	0.011*	0.009*	0.006	0.009	0.036***	0.030**
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
STR × STR_ ENDW	-0.014	-0.021	0.020	-0.002	0.014	0.026
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.07)
MCH × MCH_ ENDW	-0.064*	0.005	-0.046	0.112*	-0.068	0.052
	(0.04)	(0.04)	(0.06)	(0.07)	(0.06)	(0.11)
ICT ×Δ ICT_ENDW	0.044***	0.046***	0.024**	0.013	0.055**	0.041
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)
STR ×Δ STR_ENDW	-0.008	-0.097	0.088	-0.005	-0.035	0.016
	(0.11)	(0.11)	(0.15)	(0.14)	(0.21)	(0.26)
MCH ×Δ MCH_ENDW	-0.203*	0.005	-0.045	0.361*	-0.111	0.161
	(0.12)	(0.15)	(0.20)	(0.21)	(0.28)	(0.31)
HUM × ICT_ENDW	-0.000		0.010***		0.017	
	(0.00)		(0.00)		(0.01)	
HUM × STR_ ENDW	-0.020		-0.001		0.070	
	(0.03)		(0.03)		(0.08)	
HUM × MCH_ ENDW	0.004		-0.043		-0.084	
	(0.03)		(0.04)		(0.09)	
ICT × Y		-0.015		-0.075		0.083
		(0.07)		(0.08)		(0.22)
STR × Y		-0.042		0.002		-0.039
		(0.03)		(0.03)		(0.08)
MCH × Y		-0.008		-0.090**		-0.143*
		(0.03)		(0.04)		(0.08)
HighVA × Y		0.239		0.216		0.764
		(0.26)		(0.34)		(0.77)
N	8394	8502	8394	8502	8394	8502
A-B 2 test (p value)	0.810	0.815	0.209	0.616	0.874	0.115
Hansen J test (p value)	0.285	0.491	0.116	0.321	0.257	0.327

* The Arellano-Bond difference GMM estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. ICT, STR, MCH, and HUM are capital intensities in ICT, structure, machinery, and human capital. HighVA is the ratio of industry value-added over gross output. K^x_ENDW is the endowment in type-x capital. ΔK^x_ENDW is the 5-year growth rate of type-x capital endowment. Y is country's aggregate real output per worker. Lagged dependent variables, country's real aggregate output per worker, and industry TFP growth index are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

Now let's turn to the estimates of the structural coherence regression. Equation (20) is augmented with interaction terms involving human capital intensity, countries' GDP per worker, industries' degree of value added and TFP growth. First, I add to Equation (20) three-way interaction terms involving human capital intensity, different types of capital endowment, and countries' GDP growth. As shown in Table 15A, the interaction terms "HUM × ICT_ENDW × GROW" and "HUM × STR_ENDW × GROW" are both negative, while the terms "HUM × MCH_ENDW × GROW" and "HUM × K_ENDW × GROW" are positive but not significant. On the other hand, the coefficients for the main interaction terms remain positive and significant. The results confirm that the structural coherence' effect on aggregate growth is not driven by human capital related factors.

Three additional factors that might influence the structural coherence effect are considered: country's development level, industry's degree of value-added, and efficiency in resource allocation according to industry productivity. The third factor is drawn from the literature on allocative efficiency (Bartelsman, Haltiwanger & Scarpetta (2008), Arnold, Nicoletti & Scarpetta (2008)), which suggests that growth is related to whether resources are efficiently distributed to firms and industries with higher productivity. According to this hypothesis, a higher correlation between industry TFP growth and output share, that is, higher allocative efficiency, should also be beneficial to aggregate growth.

Table 15A: Structural coherence and growth: additional controls

	Dependent variable: log(real output share)			
	Overall capital	ICT	Structure	Machinery
K ×K_ENDW × GROW	0.092*** (0.03)			
ICT × ICT_ENDW × GROW		0.077** (0.04)		
STR × STR_ENDW × GROW			0.171** (0.09)	
MCH × MCH_ENDW × GROW				0.341** (0.14)
HUM × K_ENDW × GROW	0.012 (0.05)			
HUM × ICT_ENDW × GROW		-0.286*** (0.11)		
HUM × STR_ENDW × GROW			-0.065 (0.05)	
HUM × MCH_ENDW × GROW				0.105 (0.13)
N	8419	8394	8424	8424
A-B 2 test (p value)	0.774	0.790	0.665	0.419
Hansen J test (p value)	0.596	0.460	0.494	0.813

* The dependent variable is the log real output share of industry. Column 1 reports estimates for K^x = overall capital; column 2-4 report results for K^x = ICT, structural and machinery capital respectively. K, ICT, STR, MCH, and HUM are capital intensities in overall, information technology, structure, machinery, and human capital. K^x _ENDW is capital-x endowment. GROW is the 5-year average aggregate real output growth rate of countries. The Arellano-Bond difference GMM estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

Table 15B presents estimates of Equation (20) with added controls involving countries' total output per worker (Y), industries degree of value added (HighVA) and industry TFP growth (TFP_GROW). The coefficients of the three-way interactions between different categories of capital intensity, countries' total output level and aggregate growth rate (K^x × Y

× GROW) are all negative except for machinery capital, which is positive and significant. The interaction "HighVA × Y × GROW" is positive in the overall capital and structure capital regressions, but is only significant in the latter. The TFP interaction term "TFP_GROW × GROW" has mostly positive coefficients, indicating that efficient resource allocation in accordance with industry productivity does seem to have a positive impact on aggregate growth, though the variable is only significant in the overall capital regression.

The main interaction term "K^x × K^x_ENDW × GROW" remains positive and significant for the overall capital, ICT capital or structure capital, as in the baseline regressions. However, the interaction for machinery capital is now insignificant. This loss of significance can be due to the fact that national income level is perhaps a better measure of machinery capital endowment than "MCH_ENDW", as the machinery capital stock does not take into account the quality and technology embodied in the capital, while these factors tend to be positively correlated with a country's development level. The fact that the newly-added control "MCH × Y × GROW" is positive and highly significant is consistent with this argument.

Table 15B: Structural coherence and growth: additional controls

	Dependent variable: log(real output share)			
	Overall capital	ICT	Structure	Machinery
K ×K_ENDW × GROW	0.159* (0.09)			
ICT × ICT_ENDW × GROW		0.029* (0.02)		
STR × STR_ENDW × GROW			0.432*** (0.16)	
MCH × MCH_ENDW × GROW				0.119 (0.12)
K × Y × GROW	-0.011 (0.04)			
ICT × Y × GROW		-0.002 (0.06)		
STR × Y × GROW			-0.589 (0.39)	
MCH × Y × GROW				0.393*** (0.15)
HighVA × Y × GROW	0.144 (0.09)	-0.016 (0.04)	0.166* (0.09)	-0.072 (0.16)
TFP_GROW × GROW	0.010* (0.01)	-0.001 (0.00)	0.002 (0.01)	0.003 (0.01)
N	8527	9445	8532	8532
A-B 2 test (p value)	0.753	0.737	0.759	0.769
Hansen J test (p value)	0.257	0.567	0.299	0.849

* The dependent variable is the log real output share of industry. Column 1 reports estimates for K^x = overall capital; column 2-4 report results for K^x = ICT, structural and machinery capital respectively. K, ICT, STR, MCH are capital intensities in overall, information technology, structure, and machinery capital. K^x _ENDW is capital-x endowment. GROW is the 5-year average aggregate real output growth rate of countries. Y is country *j*'s real aggregate output per worker at the beginning year of a period. HighVA is industry value-added over gross output ratio. TFP_GROW is the 5-year growth rate of industry TFP index. The Arellano-Bond difference GMM estimator is used in all regressions. Heteroskedasticity-robust standard errors are in the parentheses. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.01; **: p value<0.05; *: p value<0.1.

In sum, compared to the baseline results, except for the machinery capital, the main interaction terms between capital intensity, endowment and aggregate growth remain positive

and significant after adding additional controls. The effect of structural coherence on growth does not seem to be driven by other omitted factors.

VII. Conclusion

This paper examines the pattern of industrial structure change induced by factor endowment changes, and explores the linkage between structural coherence and economic growth. Here structural coherence refers to the degree that a country's industrial structure aligns with its factor endowment fundamentals.

The endowment-based structural change theory predicts that when industries differ in terms of their capital intensities, an increase in capital endowment should raise the output of the capital intensive industries relatively more, which causes the industrial composition to change along with capital accumulation. An extension of this proposition is that since structural change towards industries that intensively use a production factor is the optimal result of resource allocation as the endowment of the factor increases, any arrangement that obstructs the structural change towards alignment with the endowment fundamentals can be a detriment to economic growth.

Using data of 28 industries from 15 countries, the paper first examines whether higher capital endowment is associated with larger sizes of capital intensive industries for the overall capital and three detailed categories of capital. For the overall capital, the sizes of capital intensive industries are significantly larger with higher initial period capital endowment and with faster capital accumulation. Similar results also apply to ICT capital and partially apply to machinery and structure capital. After confirming the impact of capital endowments on industrial structure, the paper checks whether a higher level of structural coherence is related to better economic growth performance. The result shows that a country's aggregate output growth is higher when the industrial structure is more coherent with the country's endowment level in all types of capital. Quantitatively, the country-level estimation shows that the difference in structural coherence level explains about 30% of the growth differential between the 25 percentile and 75 percentile country-years. The industry-level estimates indicate a coherence effect of similar magnitude.

These results suggest that structural coherence is an important factor that should be taken into account when designing industrial policy. For example, for years there were debates in the United States on whether "what is good for General Motors is also good for America". From the perspective of structural coherence, the answer would be: it depends on the era under discussion. An industry that was structurally coherent with the country's endowment fundamental fifty years ago may no longer be so, due to continuous changes in the country's endowment mix. The government should thus have an evolving view on industries' long-term potential when considering whether a historically-important, but now troubled industry is worth public support. On a more macro level, to facilitate the evolution of industrial structure, it is important to ensure that capital and labor resources can flow across industries with relative ease, by designing policies such as investing in continuous education of the

labor force and developing a flexible financial sector that provides easy access to funding to the emerging industries and firms.

References

1. Acemoglu, D. and Guerrieri, V.: Capital deepening and non-balanced economic growth. Journal of Political Economy, vol. 116, no.3, 467-498 (2008)
2. Arellano, M. and Bond, S.R.: Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Review of Economic Studies 58, 277-297 (1991)
3. Arnold, J., Nicoletti,G. and Scarpetta, S.: Regulation, allocative efficiency and productivity in OECD countries: industry and firm-level evidence. OECD Working Paper (2008)
4. Arpaia, A., Pérez, E. and Pichelmann, K.: Understanding labor income share dynamics in Europe. European Commission Working Paper (2009)
5. Baily, M.: Macroeconomic implications of the new economy. In: Economic Policy for the Information Economy. Federal Reserve Bank of Kansas City (2001)
6. Bartelsman, E., Haltiwanger, J. and Scarpetta, S.: Cross country differences in productivity: the role of allocative efficiency. Working paper (2008)
7. Bentolila, S. and Saint-Paul, G.: Explaining movements in the labor share. The B.E. Journal of Macroeconomics, Vol. 3 (1) (2003)
8. Blanchard, O.: The medium run. Brookings Papers on Economic Activity, 2, 89-158 (1997)
9. Blum, B.: Endowments, Output, and the Bias of Directed Innovation. Review of Economic Studies (forthcoming)
10. Buera, F. J. and Kaboski, J. P.: The rise of the service economy. NBER Working Paper (2009)
11. Chenery, H. B.: Structural change and Development Policy. Oxford University Press (1979)
12. Ciccone, A. and Papaioannou, E.: Human capital, the structure of production, and growth. Review of Economics and Statistics, 91(1), 66-82 (2009)
13. de Serres, A., Scarpetta, S. and de la Maisonneuve, C.: Sectoral shifts in Europe and the united states: how they affect aggregate labour shares and the properties of wage equations. OECD Working Paper (2002)
14. Duarte, M. and Restuccia, D.: The role of the structural transformation in aggregate productivity. Quarterly Journal of Economics, v 125(1), 129–173 (2010)
15. Echevarria, C.: Changes in sectoral composition associated with economic growth. International Economics Review 38: 431-452
16. Fitzgerald, D. and Hallak, J.C.: Specialization, factor accumulation and development. Journal of International Economics, 64, 277-302 (2004)
17. Harrigan, J.: Technology, factor supplies and international specialization: testing the neoclassical model. American Economic Review, 87(4), 475-494 (1997)

18. Jones, C.I.: Growth, Capital shares, and a new perspective on production functions, Working Paper (2003)
19. Ju, J., Lin, J.Y. and Wang, Y.: Endowment structures, industrial dynamics, and economic growth. World Bank Working Paper (2009)
20. Kongsamut, P., Rebelo, S. and Xie, D.: Beyond balanced growth. Review of Economic Studies 68, 869-882
21. Laitner, J.: Structural change and economic growth. Review of Economic Studies 67, 545-561 (2000)
22. Lewis, E.: Immigration, skill mix, and the choice of technique. Federal Reserve Bank of Philadelphia Working Paper (2006)
23. Ngai, L.R. and Pissarides, C. A.: Structural change in a multi-sector model of growth. The American Economic Review 97, 429-443 (2007)
24. Oulton, N.: Must the growth rate decline? Baumol's unbalanced growth revisited. Oxford Economic Papers 53, 605-627 (2001)
25. Rogerson, R.: Structural transformation and the deterioration of European labor market outcomes. NBER Working Paper No.12889 (2007)
26. Romalis, J.: Factor proportions and the structure of commodity trade. American Economic Review, 94(1), 67-97 (2004)
27. Roodman, D.: A Note on the Theme of Too Many Instruments. CGD Working Paper 125 (2007)
28. Schott, P.: One size fits all? Theory, evidence and implications of cones of diversification. American Economic Review 93(3), 686-708 (2003)
29. van Ark, B., O'Mahony, M. and Timmer, M.P.: The productivity gap between europe and the united states: trends and causes. Journal of Economic Perspectives, Volume 22(1), 25-44 (2008)