# Factor Endowment, Structural Change, and Economic Growth

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15 April 2010

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*April 2010*

**Abstract**

This paper aims (1) to test the endowment-based structural change theory proposed by recent studies such as Acemoglu & Guerrieri (2008) and Ju, Lin & Wang (2009); and (2) to explore the linkage between structural coherence and economic growth. By structural coherence, I refer to the degree that a country's industrial structure optimally reflects its factor endowment fundamentals.

Using data from 27 industries across 15 countries, I examine whether higher capital endowment is associated with larger sizes in capital intensive industries for overall fixed capital as well as for three detailed categories of capital – information and communication technology capital (ICT), non-residential structure, and machinery. For the overall capital, I found that the real and nominal output share and employment share of capital intensive industries were significantly bigger with higher initial capital endowment and with faster capital accumulation. This result also applies to ICT capital and partially applies to machinery and structure capital. In addition, the labor income share of capital intensive industries is found to be negatively associated with capital endowment and capital accumulation in most types of capital, which provides one way to understand the relationship between structural change and the decline of labor income share in many sample countries during recent decades. Finally, I test whether a higher level of coherence between capital endowment and industrial structure is related to better economic growth performance. The result shows a significantly positive relationship between a country's aggregate output growth and the degree of structural coherence in all types of capital. Quantitatively, the structural coherence with respect to the overall capital explains about 35% of the growth differential among sample countries.

The results of the paper are mostly robust to alternative measure of capital intensity, to controls for other industry characteristics such as human capital and degree of value-added, and to controls for other determinants of structural change on both demand side and supply side.

## 1. Introduction

The purposes of this paper are twofold. The first is to test the predictions of factor-endowment-based theories of structural change. The second is to examine the relationship between economic growth and the "coherence" level of a country's industrial structure with its capital endowment.

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. They also argue that when the industrial structure is not consistent with the capital endowment level, it can lead to suboptimal economic growth performance.[2]

This 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, 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. 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] It is beyond the scope of the current study to identify specific causes of structural incoherence.

This paper aims to test the above predictions empirically. In addition, it examines the change in labor income share along the structural change process. Most theoretical structural change literature strives to be consistent with the Kaldor facts – the proposition that growth rate of output, capital-output ratio, real interest rate and labor income share are relatively stable over time. Though very well-known in Macroeconomic literature, these

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[1] Other explanations of structural change also exist. On the supply side, Ngai & Pissarides (2007) derives 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)). In the empirical regressions, I control for factors other than capital endowment changes.

[2] In a much earlier work, Hollis Chenery (1979) made a similar point. He advocates 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] From different perspectives than the present paper, the linkage between structural change and aggregate economic performance have been discussed in recent macroeconomic literature; see for example, Nickell, Redding & Swaffield (2004), Rogerson (2007), van Ark, O'Mahony & Timmer (2008), and Baily (2001).

"facts" may not apply over extended periods and especially when the economy is going through dramatic structural transformation. Empirical evidence suggests that labor income share in most developed countries have been declining since the mid 1980s (e.g., Blanchard (1997); Bentolila & Saint-Paul (2003); de Serres, Scarpetta & de la Maisonneuve (2002); Arpaia, Perez & Pichelmann (2009)). Some of these studies emphasize capital accumulation and sectoral composition change as driving forces of the decline in labor income shares. These arguments will be examined in this paper.

Here is an overview of the main empirical results. In general, the capital-intensive industries' output and employment sizes are larger when capital endowment is higher, and growth in capital endowment leads industrial structure to shift towards capital-intensive industries. These results apply to overall capital[4] endowment and to a large extent to endowments in three detailed types of capital – information technology capital (ICT), machinery and non-residential structure – as well.[5] At the same time, capital-intensive industries' labor income share decreases when capital endowment is higher. This result thus suggests that capital deepening combined with structural change towards capital intensive industries help explain the decrease in labor income share in many sample countries over recent decades. Finally, the result shows that the aggregate growth performance is significantly and positively associated with the coherence level between industrial structure and capital endowment. These results are mostly robust to changing measurements of capital intensity and 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.[6] 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.[7] 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 they often use industry characteristics in one country as proxies for all other countries. Though a reasonable assumption when countries are relatively similar, this assumption is not

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[4] The overall capital is the sum total of the three detailed categories of capital.

[5] 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 at a cross-country setting due to data limitations.

[6] 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.

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

necessarily true as I will show in the next section.[8] In this paper I allow 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 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 summarizes the data and defines measures of variables. Section 3 presents the main empirical models and discusses the results. I add more restrictions to the empirical model and conduct robustness checks in Section 4. Section 5 concludes.

## 2. Data and Variables

The data used in this paper is from 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.[9] 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.[10] Industries are sorted by 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 more 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

[8] 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.

[9] 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.

[10] Capital intensity is calculated as industry real capital stock over real output.

that although the service industries are generally not intensive in machinery capital, they are more intensive in information technology capital and non-residential 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 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.

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

| NACE code | industry | Median share growth rate from 1970 to 2005 | | | Median capital intensity (Overall capital stock/output) |
|---|---|---|---|---|---|
| | | Real output share | Employment share | Nominal output share | |
| 17t19 | Textiles, Textile , Leather And Footwear | -1.323 | -1.891 | -1.673 | 0.512 |
| C | Mining And Quarrying | -0.758 | -0.781 | -0.555 | 1.696 |
| 23 | Coke, Refined Petroleum And Nuclear Fuel | -0.620 | -0.853 | -0.064 | 0.510 |
| 15t16 | Food , Beverages And Tobacco | -0.431 | -0.603 | -0.584 | 0.436 |
| F | Construction | -0.422 | -0.301 | -0.205 | 0.232 |
| 20 | Wood And Of Wood And Cork | -0.325 | -0.494 | -0.385 | 0.508 |
| H | Hotels And Restaurants | -0.299 | 0.519 | 0.017 | 0.708 |
| 26 | Other Non-Metallic Mineral | -0.285 | -0.671 | -0.434 | 0.734 |
| 36t37 | Manufacturing Nec; Recycling | -0.193 | -0.399 | -0.253 | 0.477 |
| 21t22 | Pulp, Paper, Paper , Printing And Publishing | -0.175 | -0.491 | -0.231 | 0.538 |
| M | Education | -0.119 | 0.283 | 0.189 | 1.493 |
| 27t28 | Basic Metals And Fabricated Metal | -0.114 | -0.552 | -0.316 | 0.600 |
| 52 | Retail Trade | 0.008 | 0.155 | -0.016 | 0.824 |
| 50 | Sale, Maintenance And Repair Of Motor Vehicles And Motorcycles | 0.037 | 0.088 | 0.026 | 0.616 |
| O | Other Community, Social And Personal Services | 0.043 | 0.414 | 0.399 | 1.209 |
| 51 | Wholesale Trade And Commission Trade | 0.106 | 0.005 | 0.001 | 0.550 |
| 70 | Real Estate Activities | 0.145 | 0.697 | 0.532 | 0.566 |
| 60t63 | Transport And Storage | 0.147 | -0.017 | 0.099 | 1.868 |
| N | Health And Social Work | 0.152 | 0.633 | 0.514 | 0.921 |
| 29 | Machinery, Nec | 0.176 | -0.299 | -0.044 | 0.442 |
| 24 | Chemicals And Chemical Products | 0.197 | -0.559 | -0.081 | 0.754 |
| E | Electricity, Gas And Water Supply | 0.279 | -0.383 | 0.194 | 3.424 |
| 25 | Rubber And Plastics | 0.301 | -0.113 | 0.112 | 0.581 |
| 34t35 | Transport Equipment | 0.335 | -0.264 | 0.064 | 0.510 |
| J | Financial Intermediation | 0.501 | 0.222 | 0.502 | 0.708 |
| 30t33 | Electrical And Optical Equipment | 0.715 | -0.331 | 0.054 | 0.496 |
| 71t74 | Renting Of M&Eq And Other Business Activities | 0.826 | 1.218 | 0.979 | 0.555 |
| 64 | 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.

Figure 1 and Table 2 present the trend of labor income shares by country. In 13 out of the 15 countries covered, labor's share has declined over the sample period. The result is consistent with previous studies on the trend of labor income share in these countries, as reviewed in the introduction section.

**Figure 1: Evolution of labor income share by country**

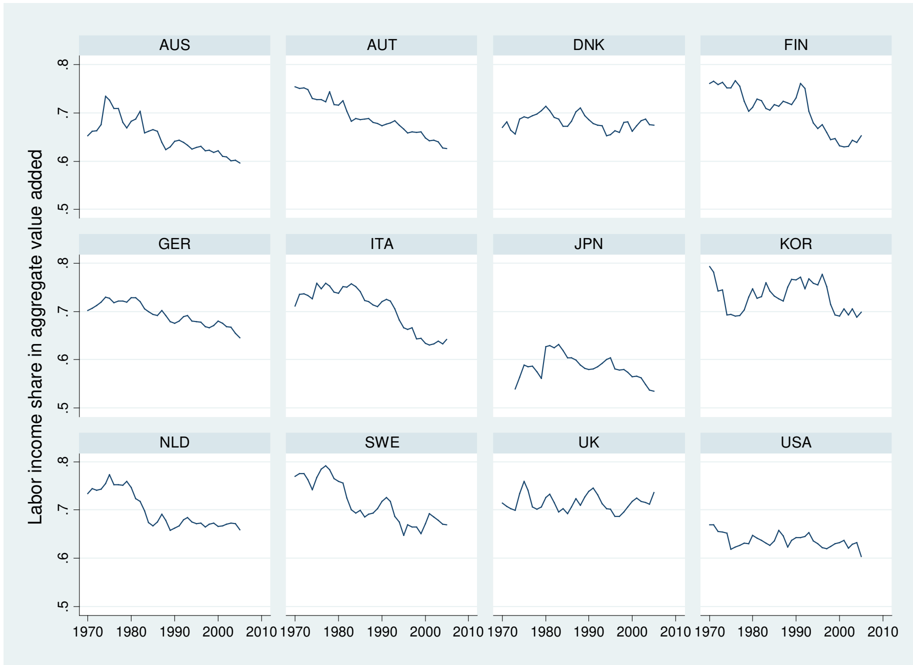



**Table 2: Evolution of labor income share over time**

| | Labor share | | | |
|---|---|---|---|---|
| country | 1975 | 1995 | 2005 | change: 1975 - 2005 |
| AUS | 0.727 | 0.629 | 0.596 | -0.131 |
| AUT | 0.728 | 0.666 | 0.627 | -0.101 |
| CZE | n.a. | 0.567 | 0.596 | 0.029 |
| DNK | 0.692 | 0.656 | 0.675 | -0.017 |
| FIN | 0.752 | 0.668 | 0.653 | -0.099 |
| GER | 0.727 | 0.679 | 0.646 | -0.081 |
| ITA | 0.759 | 0.666 | 0.643 | -0.116 |
| JPN | 0.589 | 0.604 | 0.535 | -0.055 |
| KOR | 0.694 | 0.755 | 0.698 | 0.005 |
| NLD | 0.773 | 0.672 | 0.658 | -0.115 |
| PRT | 0.681 | 0.653 | 0.656 | -0.025 |
| SVN | n.a. | 0.838 | 0.719 | -0.119 |
| SWE | 0.768 | 0.647 | 0.670 | -0.098 |
| UK | 0.759 | 0.702 | 0.736 | -0.023 |
| USA | 0.619 | 0.630 | 0.603 | -0.016 |

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

With respect to factor endowment measures, 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 many different types of capitals, whose positions 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 will allow us see if the theories' predictions can universally apply to different production factors. Therefore, in addition to the overall capital, this paper includes three detailed categories of capital in the examination: ICT, machinery and non-residential structure. Endowment for these detailed types of capital is more complicated to measure than the overall capital. Although the absolute stocks for all three types of capital have been increasing over time for all countries, their relative importance in total capital stock has changed considerably. Figure 2 reports the share changes of each type of capital in total capital stock by country. 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, a good 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. Therefore, I calculate capital-x endowment as the log of capital-x stock over the total labor in a country multiplied by the share of capital-x ( $K^x$ ) in overall capital stock( $K$ ):

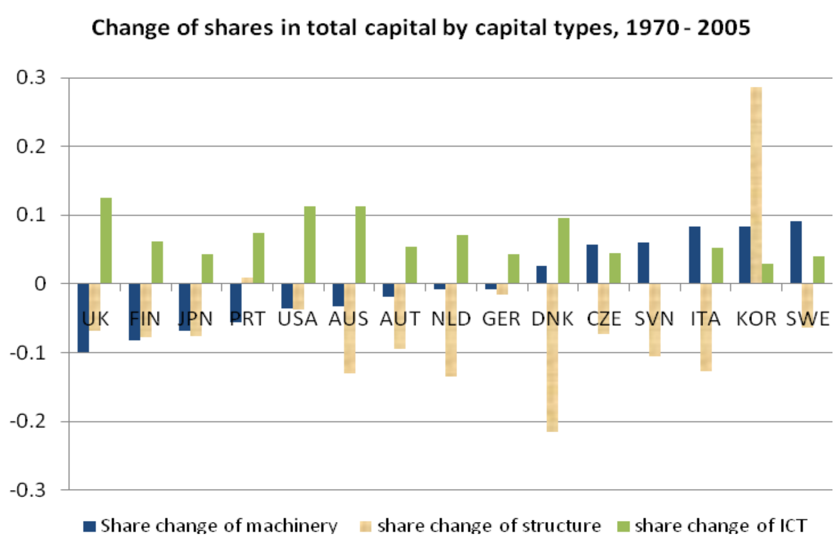
$$\ln K^x\_ENDW_{j,t} = \ln\left[\left(K^x_{jt} / L_{jt}\right)\times\left(K^x_{jt} / K_{jt}\right)\right]$$

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

$$\Delta \ln K^x\_ENDW = \frac{\Delta\widetilde{K}^x}{\widetilde{K}^x} + \left(\frac{\Delta\widetilde{K}^x}{\widetilde{K}^x} - \frac{\Delta\widetilde{K}}{\widetilde{K}}\right)$$

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

**Figure 2**




Industry's capital stock-real output ratio is used as the main measure of capital intensity.[11] For robustness check, I also use capital's income share in industry value-added as an alternative capital intensity 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 contributing to 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 difference 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, I use the standard score of capital intensities instead of the raw capital-output ratio 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 is mainly a measure of within-country variations of capital intensity across industries at a certain time.

**Figure 3**

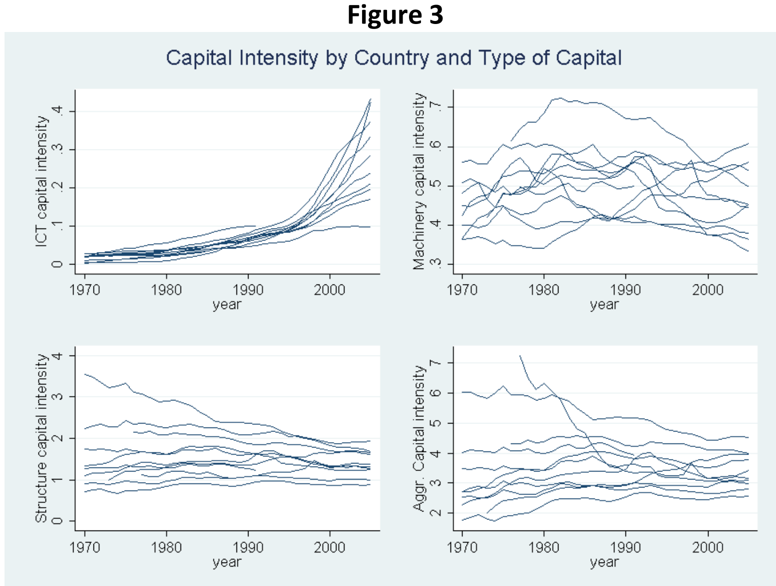


**Table 3: Regression of capital intensity on country capital endowment by industry**

| Industry code | ICT capital | | | Machinery capital | | | Structure capital | | |
|---|---|---|---|---|---|---|---|---|---|
| | $b_1$ | 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 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. I will revisit the question later in the robustness check section. 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. Thus in the robustness check section, I also include human capital-related variables as additional controls.

**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 |
| Labor income share | 11033 | 0.679 | 0.201 | 0.013 | 0.980 |
| High-skill labor's income in total labor income | 10133 | 0.179 | 0.158 | 0.002 | 0.834 |

* 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 per capita GDP | 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 |
|---|---|---|---|---|---|
| Overall capital intensity index | 1.00 | | | | |
| ICT intensity index | 0.19 | 1.00 | | | |
| Structure intensity index | 0.80 | 0.31 | 1.00 | | |
| Machinery intensity index | -0.01 | 0.17 | 0.10 | 1.00 | |
| Human capital intensity index | 0.27 | 0.22 | 0.19 | -0.36 | 1.00 |

# 3. Empirical Results

## 3.1 Capital Endowment and Structural Change

Although the theoretical literature on structural change generally assumes that capital and labor are freely mobile across sectors, in reality resources cannot be moved instantly. Neither is it likely that they would have an effect on output immediately after applied. To allow for the slow adjustment process, I set the unit of time period to be 5 years in the estimation. The basic estimation equation used for testing the linkage between capital endowment and industrial structure is

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

where the dependent variable is the log of real output share, employment share, nominal output share or labor income share of industry *i* in country *j* in the last year of a 5-year period; $\mathrm{K}^x_{ij,t-1}$ is the standardized capital-x intensity of industry *i* in country *j* at the beginning year of the 5-year period (*x* can be overall capital, ICT, non-residential structure or machinery capital); $\mathrm{K}^x\_\mathrm{ENDW}_{j,t-1}$ is the capital-x endowment in country j in the same year.

Equation 1 does not account for the possibility that contemporary increase in capital endowment can also impact industrial structure. To allow for the endowment growth effect, I augment equation 1 by adding country-level capital endowment growth over 5-year period and its interaction with initial-year industry capital intensity:

$$\begin{aligned}\ln Y_{ij,t} = a_1 + a_2\mathrm{K}^x_{ij,t-1} + a_3(\mathrm{K}^x_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1}) + a_4(\mathrm{K}^x_{ij,t-1} \times \Delta\mathrm{K}^x\_\mathrm{ENDW}_{j,t}) + a_5\mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \\ + a_6\Delta\mathrm{K}^x\_\mathrm{ENDW}^t_{j,t} + a_7 Z^{'}_{ijt} + a_8 \ln Y_{ij,t-1} + e_{ijt}\end{aligned} \quad (2)$$

where $\Delta\mathrm{K}^x\_\mathrm{ENDW}_{j,t}$ 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 *t*-1 and the 5-year growth rate of industry's TFP index.[12] To control for the initial difference in the dependent variable, $\ln Y_{ij,t-1}$ is also included in the explanatory variables. The error term consists of a country-industry fixed effect and an observation specific error: $e_{ijt} = u_{ij} + \varepsilon_{ijt}$.

According to Equations 1 and 2, the capital-x endowment effect and endowment growth effect on the dependent variable $\ln Y_{ij}$ are respectively

$$\frac{\partial \ln Y_{ij,t}}{\partial \mathrm{K}\_\mathrm{ENDW}_{j,t\text{-}1}} = a_3\mathrm{K}^x_{ij,t-1} + a_5, \text{ and } \frac{\partial \ln Y_{ij,t}}{\partial \Delta\mathrm{K}\_\mathrm{ENDW}_{j,t}} = a_4\mathrm{K}^x_{ij,t-1} + a_6 \quad (3)$$

Both of the two terms are linear functions of $\mathrm{K}^x_{ij,t-1}$, the capital-x intensity score of industry *i*. According to the endowment-based structural change theory, when capital-x endowment is higher, the industries that use capital-x intensively (industries with high $\mathrm{K}^x_{ij}$) 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. In other words, the industrial structure shifts towards more capital intensive industries when capital becomes more abundant and when capital accumulates faster. The intercepts $a_5$ and $a_6$ help determine the magnitudes of the capital endowment on $\ln Y_{ij}$.

Keep in mind that $\mathrm{K}^x_{ij,t-1}$ is the standard score of capital-x intensity. It captures the 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 2 and in Blum (2010). By standardizing capital intensities, I make sure that the intercepts of the

[12] Ngai & Pissarides (2007) identifies different TFP growth rate across-industries as a driving force of structural change.

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.

When $Y_{ij}$ is the employment share or nominal output share, the signs of $a_3$ and $a_4$ are more ambiguous. They depend, in Acemoglu & Guerrieri (2008)'s two-sector, close-economy model, on the elasticity of substitution between sectors, as the elasticity of substitution determines the degree of changes in relative prices in response 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 are probably 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, most of the countries in the sample are open economies. Hence especially for tradable industries in small countries, domestic demands may have little impact on goods prices. Although these factors complicate the prediction for the signs of the interaction terms in employment and nominal output regressions, they do not seem to interfere with the prediction that industry's employment share and nominal output share will move in the same direction.

Bentolila & Saint-Paul (2003) found at the industry level a negative relationship between labor's income share and k/y ratio. Arpaia, Perez & Pichelmann (2009) relates the decline in European countries' labor income share to capital deepening and structural change. However, these studies do not identify any specific channels of causality from those variables to the decline in labor share. This paper makes a step further by examining one possible channel that integrates the results of previous studies. Specifically, I test whether capital intensive industries' labor income share decreases when capital endowment is higher. If this is the case, then $a_3$ and $a_4$ should be negative when industry's labor income share is the dependent variable. If the endowment-based structural change theory is also confirmed by the empirical test, we can then establish a linkage between structural change and decline in labor income share through one mutual cause, that is, capital accumulation.

The error term in Equations 1 and 2 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. To correct these problems, I use 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 1 and 2 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 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

[13] Suppose that instead of a standard score, the raw capital intensity $\tilde{k}_{ij}$ , which is a function of capital endowment in country *j*, is used in the estimation. The endowment effect on $Y_{ij}$ is thus:

$\partial \ln Y_{ij} / \partial \text{K\_ENDW}_j = (a_2 + a_3)\partial \widetilde{k_{ij}} / \partial \text{K\_ENDW}_j + a_3 + a_3 \widetilde{k_{ij}}$ . The intercept term $(a_2 + a_3)\partial \widetilde{k_{ij}} / \partial \text{K\_ENDW}_j + a_3$ is not constant unless $\partial \widetilde{k_{ij}} / \partial \text{K\_ENDW}_j$ is invariant with respect to K_ENDW.

country and time is the basis to test the relationship between structural coherence and economic growth, which will be specified in section 3.2.

### 3.1.1 Overall capital

Table 5 shows the regression results of Equations 1 and 2 for the overall capital. 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 1st column under each explanatory variable heading reports the results of Equation 1, the 2nd column of Equation 2. The regression model is not likely to be susceptible to country-level endogeneity problem, as the value of the dependent variable varies at the industry level within a country. Industry-level endogeneity should not be a major concern either, given that our interest is with the interaction terms.[14] That being said, to eliminate any potential endogeneity problems, I also use IV method to estimate Equation 2 with two-period lagged capital intensity and capital endowment as instruments. The result is reported in the 3rd column under each dependent variable heading.

For all the three industry size regressions, the coefficients of capital endowment interaction and endowment growth interaction are positive and significant at 1% level, except for the “basic 1” regression (column 4) when employment share is the dependent variable. 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. IV estimates do not significantly differ from the basic regressions. In fact, the coefficients for both interaction terms increase and become somewhat more significant when IV estimation is used. Although not a direct proof against it, the results do not seem to support the proposition that the elasticity of substitution across different industries’ products is less than one. Also notice that 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. This result is consistent with the theoretical prediction of Ngai& Pissarides (2007).

It is worthwhile to look at the impact of capital endowment on industrial structure at a more quantitative level. According to the estimates of $a_3$ to $a_6$ in Equation 2 for real output share (column 2), industries whose real output shares increase with higher capital endowment on average have a standard score of capital intensity greater than -0.28; and for industries to expand with capital accumulation, their capital intensity scores should be greater than -0.22. Both numbers are between 50 and 55 percentiles of the within-country industry capital intensity ranking. In other words, among all the industries within a country, about half of them with relatively high capital intensity will expand with an increase in capital endowment. On the other hand, the estimates of Equation 2 for employment share (column 5) show that for an industry’s employment share to increase with higher capital endowment and capital accumulation, the cutoff values of capital intensity score are 0.21 and

[14] Suppose there is an industry-wise positive exogenous shock that simultaneously increase capital intensity and future output growth rate of the industry. The coefficient for capital intensity variable (K) will be upward biased. However, for “K × K_ENDW” to be biased, it has to be the case that the bias in K caused by exogenous shocks increases/decreases with capital endowment of a country. Intuitively, this is not a very likely scenario.

0.15 respectively. These numbers are between 63 and 65 percentiles of the capital intensity scores; that is, around 35 percent of industries on the high end of capital intensity will grow in terms of employment share when capital endowment is higher.

When labor income share is the dependent variable, the coefficients of both interaction terms are negative and significant at 1% level. This result thus suggests one specific channel of the recent decline in labor income share in many sample countries. Namely, when capital becomes more abundant, labor income share declines in industries that are relatively capital-intensive; since these are also the industries that become a bigger part of the economy when capital endowment is higher, the country-level labor income share declines as the industrial structure changes towards capital intensive industries. The result from a different perspective supports de Serres, Scarpetta & de la Maisonneuve (2002), which argues that the decline in labor share in certain EU countries and in US partly reflects the changes in industrial composition.

**Table 5: Overall capital and structural change: baseline estimation**

| | log (Real output share) | | | log(Employment share) | | | log(Nominal output share) | | | log(Labor income share ) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Basic 1 | Basic 2 | Iv | Basic 1 | Basic 2 | Iv | Basic 1 | Basic 2 | Iv | Basic 1 | Basic 2 | Iv |
| K × K_ENDW | 0.0339*** | 0.0926*** | 0.1754*** | 0.0134 | 0.1335*** | 0.1794*** | 0.1123*** | 0.1783*** | 0.3112*** | -0.0225* | -0.0408*** | -0.0638*** |
| | (0.0078) | (0.0085) | (0.011) | (0.0073) | (0.0077) | (0.0106) | (0.0103) | (0.0112) | (0.0144) | (0.0113) | (0.0121) | (0.0151) |
| K × ΔK_ENDW | | 0.3677*** | 0.9098*** | | 0.7049*** | 1.1804*** | | 0.4078*** | 0.8731*** | | -0.1908*** | -0.5344*** |
| | | (0.0213) | (0.0381) | | (0.0162) | (0.0226) | | (0.0279) | (0.0499) | | (0.0332) | (0.0538) |
| K_ENDW | 0.0177* | 0.026* | 0.0973*** | 0.0514*** | -0.0135 | -0.0385* | 0.0019 | 0.0154 | 0.0701*** | 0.0812*** | 0.0308 | -0.0419* |
| | (0.0086) | (0.0107) | (0.0131) | (0.0085) | (0.0109) | (0.0152) | (0.0113) | (0.014) | (0.0171) | (0.0145) | (0.0177) | (0.0212) |
| ΔK_ENDW | | 0.0797*** | 0.2703*** | | -0.0866*** | -0.1756*** | | 0.101*** | 0.2856*** | | -0.123*** | -0.1086*** |
| | | (0.0195) | (0.0268) | | (0.0173) | (0.0237) | | (0.0255) | (0.0349) | | (0.0278) | (0.0329) |
| TFP growth | 0.0102*** | 0.0102*** | 0.0101*** | 0.0013*** | 0.0008*** | 0.0005** | 0.0073*** | 0.0073*** | 0.0074*** | -0.0066*** | -0.0066*** | -0.0061*** |
| | (0.0001) | (0.0001) | (0.0002) | (0.0001) | (0.0001) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0003) |
| N | 8532 | 8532 | 7884 | 8532 | 8532 | 7884 | 8532 | 8532 | 7884 | 8319 | 8319 | 7728 |

* The dependent variable is the log real output share of industry for column 1-3, the log employment share of industry for column 4-6, the log nominal output share of industry for column 7-9, and the log labor income share in industry value-added for column 10-12. The Arellano-Bond difference GMM estimator is used in all regressions. The explanatory variables are treated as exogenous in Basic1 and Basic2 columns. IV columns report estimates using lagged two-period capital intensity and capital endowment as additional instruments in the regression. 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<0.001; **: p value<0.01; *: p value<0.05.

### 3.1.2 Detailed Categories of Capital

Table 6 reports estimates of equation 1 and 2 when $K^x$ s are the intensities of information and communication technology capital (ICT), non-residential structure (STR) and machinery (MCH). Again, the 1st and 2nd columns under each explanatory variable heading report the basic regression results. The 3rd column reports IV estimates where factor intensities and endowments are treated as endogenous.

Compared to the results for overall capital, the relationships between detailed types of capital endowment and industry growth are more of a mix. When industry share is the dependent variable, the two interaction terms for ICT capital are positive and significant at the 1% level (the $1^{st}$ and $4^{th}$ rows of table 6), no matter which of the three measures of industry size is used. The magnitudes of coefficients are greater for nominal and real output share than for employment share.

As for structure capital, the interaction term involving initial structure endowment (the $2^{nd}$ row) is negative for real and nominal output share and positive for employment share. The coefficients are all significant except for the IV estimate in the real output growth regression. The interaction between structure intensity and structure endowment growth (the $5^{th}$ row) enter with a positive and significant sign in the real output and employment growth regressions, but is negative, though less significant, in the nominal growth regression. The results suggest that structure capital intensive industries' real output and employment grow faster as structure endowment accumulates, but their nominal growth is lower with higher structure capital endowment. Notice that for structure capital, the interaction terms have opposite signs in the employment growth regression and in the nominal output growth regression, which does not seem to be consistent with the theoretical prediction with constant elasticity of substitution between industrial goods. On the other hand, for both of the other two types of capital, the interaction terms have the same sign in the two regressions.

Next let's look at machinery capital. The interaction term for initial machinery endowment (the $3^{rd}$ row) is negative in the employment and nominal output growth regressions, and positive in the basic real output growth regressions. However, in the latter when factor intensities are treated as endogenous, the term becomes insignificant and negative. The interaction term of machinery endowment growth is negative and significant for all three measures of industry growth.

All in all, when different categories of capital are treated as separate production factors, the results are only partially consistent with the endowment-based structural change story. Especially when industry real output growth is concerned, the results for structure and machinery capital seem to violate what the theory would predict. However, we shall keep in mind that the theoretical result only describes the "no-friction" scenario and does not take into account such realistic factors as inefficiencies in resource allocation and non-competitive market structures. No matter what these factors are, if the sectoral structures that they lead to are indeed sub-optimal, we shall observe a negative relationship between deviations from the optimal structural change path and economic growth performance. The next section will investigate this relationship.

Finally, let's look at the labor income share regressions (columns 10 – 12). Consistent with the result for overall capital, both interaction terms for ICT and structure capital are negative and significant except for the coefficient of "ICT ×ΔICT_ENDW" . However, the two interaction terms for machinery capital are both positive and significant, which may suggests that machinery capital has very different elasticity of substitution with respect to labor than the other two types of capital.

**Table 6: Detailed types of capital and structural change: baseline estimation**

| | log (Real output share) | | | log(Employment share) | | | log(Nominal output share) | | | log(Labor income share ) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Basic 1 | Basic 2 | Iv | Basic 1 | Basic 2 | Iv | Basic 1 | Basic 2 | Iv | Basic 1 | Basic 2 | Iv |
| ICT × ICT_ENDW | 0.0295*** | 0.0367*** | 0.0506*** | 0.0269*** | 0.0301*** | 0.0425*** | 0.0313*** | 0.0372*** | 0.0598*** | -0.0042* | -0.0086*** | -0.0172*** |
| | (0.001) | (0.0011) | (0.0015) | (0.0009) | (0.0009) | (0.0012) | (0.0013) | (0.0013) | (0.0018) | (0.0018) | (0.002) | (0.0029) |
| STR × STR_ ENDW | -0.0217*** | -0.0036 | 0.0062 | 0.0194*** | 0.0722*** | 0.1247*** | -0.0815*** | -0.0646*** | -0.1036*** | -0.0688*** | -0.068*** | -0.1424*** |
| | (0.005) | (0.0055) | 0.0072 | (0.0041) | (0.0045) | (0.006) | (0.0069) | (0.0077) | (0.01) | (0.0099) | (0.0113) | (0.016) |
| MCH × MCH_ ENDW | 0.0339*** | 0.0192*** | 0.0221** | -0.1003*** | -0.1314*** | -0.1911*** | -0.0537*** | -0.0916*** | -0.1585*** | -0.0118 | -0.0018 | 0.0095 |
| | (0.0044) | (0.005) | (0.0071) | (0.0036) | (0.0041) | (0.0054) | (0.0057) | (0.0067) | (0.0103) | (0.0076) | (0.009) | (0.0138) |
| ICT × ΔICT_ENDW | | 0.0602*** | 0.0794*** | | 0.0342*** | 0.0024 | | 0.0373*** | 0.0231*** | | -0.0229*** | -0.0485*** |
| | | (0.0029) | (0.0048) | | (0.0025) | (0.0044) | | (0.0036) | (0.0061) | | (0.0049) | (0.0093) |
| STR × ΔSTR_ENDW | | 0.1538*** | 0.3231*** | | 0.3281*** | 0.7189*** | | 0.0829*** | 0.121*** | | -0.051* | -0.2369*** |
| | | (0.0143) | (0.0237) | | (0.0122) | (0.0203) | | (0.0178) | (0.0294) | | (0.0256) | (0.049) |
| MCH × ΔMCH_ENDW | | -0.0626*** | -0.215*** | | -0.1206*** | -0.1691*** | | -0.1287*** | -0.4511*** | | 0.0305 | 0.0815** |
| | | (0.0105) | (0.0186) | | (0.0081) | (0.0117) | | (0.013) | (0.0229) | | (0.0174) | (0.0305) |
| ICT_ENDW | 0.0295*** | 0.0367*** | 0.0506*** | 0.0269*** | 0.0301*** | 0.0425*** | 0.0313*** | 0.0372*** | 0.0598*** | -0.0042* | -0.0086*** | -0.0172*** |
| | (0.001) | (0.0011) | (0.0015) | (0.0009) | (0.0009) | (0.0012) | (0.0013) | (0.0013) | (0.0018) | (0.0018) | (0.002) | (0.0029) |
| STR_ENDW | -0.0217*** | -0.0036 | 0.0062 | 0.0194*** | 0.0722*** | 0.1247*** | -0.0815*** | -0.0646*** | -0.1036*** | -0.0688*** | -0.068*** | -0.1424*** |
| | (0.005) | (0.0055) | (0.0072) | (0.0041) | (0.0045) | (0.006) | (0.0069) | (0.0077) | (0.01) | (0.0099) | (0.0113) | (0.016) |
| MCH_ENDW | 0.0339*** | 0.0192*** | 0.0221** | -0.1003*** | -0.1314*** | -0.1911*** | -0.0537*** | -0.0916*** | -0.1585*** | -0.0118 | -0.0018 | 0.0095 |
| | (0.0044) | (0.005) | (0.0071) | (0.0036) | (0.0041) | (0.0054) | (0.0057) | (0.0067) | (0.0103) | (0.0076) | (0.009) | (0.0138) |
| ΔICT_ENDW | | -0.0017 | 0.0022 | | -0.0044 | -0.005 | | 0.0165*** | 0.0316*** | | -0.021*** | -0.0386*** |
| | | (0.0027) | (0.0032) | | (0.0025) | (0.0033) | | (0.0033) | (0.004) | | (0.0045) | (0.0058) |
| ΔSTR_ENDW | | 0.0024 | -0.007 | | -0.0401*** | -0.0355** | | -0.0457*** | -0.0746*** | | 0.1147*** | 0.1335*** |
| | | (0.0088) | (0.0119) | | (0.0084) | (0.0125) | | (0.011) | (0.0156) | | (0.0144) | (0.0188) |
| ΔMCH_ENDW | | 0.1153*** | 0.2011*** | | 0.0368** | 0.1841*** | | 0.0688*** | 0.1441*** | | -0.1286*** | -0.1661*** |
| | | (0.014) | (0.0205) | | (0.0121) | (0.0195) | | (0.0174) | (0.0255) | | (0.023) | (0.0327) |
| TFP growth | 0.0097*** | 0.0096*** | 0.0095*** | -0.0014*** | -0.0014*** | -0.0022*** | 0.0034*** | 0.0033*** | 0.0028*** | -0.0064*** | -0.0061*** | -0.0049*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0002) | (0.0003) |
| N | 8502 | 8502 | 7854 | 8502 | 8502 | 7854 | 8502 | 8502 | 7854 | 8289 | 8289 | 7698 |

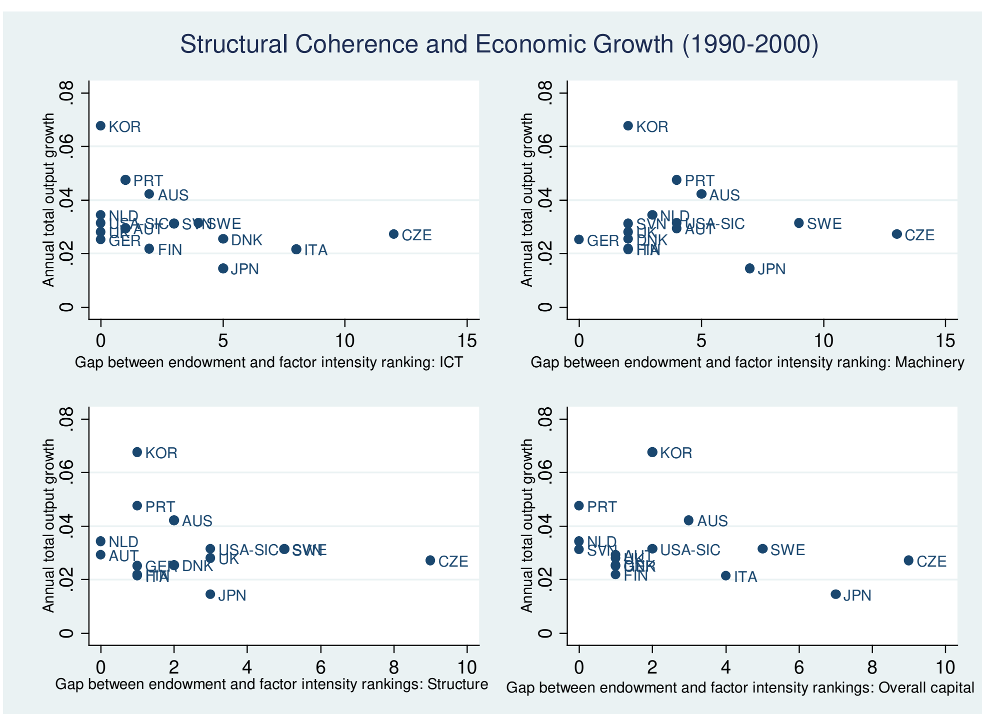
* The dependent variable is the log real output share of industry for column 1-3, the log employment share of industry for column 4-6, the log nominal output share of industry for column 7-9, and the log labor income share in industry value-added for column 10-12. The Arellano-Bond difference GMM estimator is used in all regressions. The explanatory variables are treated as exogenous in Basic1 and Basic2 columns. IV columns report estimates using lagged two-period capital intensity and capital endowment as additional instruments in the regression. ICT, STR and MCH are capital intensities in information technology, structure and machinery capital. $K^x$ _ENDW is capital-x endowment. $\Delta K^x$ _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<0.001; **: p value<0.01; *: p value<0.05.

### 3.2 Structural Coherence and Economic Growth

I use 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 industries which use a production factor intensively expand when the endowment of the factor accumulates, given no distortions to the market system and to individual agents' decision making. An interesting question to ask is: what would happen if the industrial structure does not evolve in accordance with the changes in the country's endowment fundamentals? What is the impact on growth and welfare if the industrial structure is not coherent with the endowment structure? Previous studies have shown that structural change characteristics do have aggregate effects on countries' labor market performance (Rogerson, 2007) and on aggregate productivity (van Ark, O'Mahony & Timmer, 2008; Duarte & Restuccia, 2010). This section will examine the relationship between structural coherence and economic growth.

Figure 4 gives a rough presentation of this relationship. The graphs are constructed in the following way. The 15 sample countries are ranked according to their (1) factor endowments in overall capital and three detailed types of capital, averaged between 1990 and 2000; and (2) weighted average factor intensities in the four capital categories over the same period. A country's "structural coherence score" in capital-x is defined as the absolute gap between the two rankings for type-x capital. Intuitively, the smaller the gap is, the more a country's industrial structure is in alignment with its capital-x endowment. Figure 4 plots countries' annual real GDP growth rate over the 1990s against their coherence scores. It is clear from the graphs that in general, there is a positive relationship between structural coherence level and aggregate growth for the time period covered. The relationship is present, though to various degrees, for all three detailed types of capital and for the overall capital as well.

**Figure 4: Relationship between structural coherence and aggregate growth**



The information revealed by a static graphic presentation is however limited, as the industrial structure is in constant shift and it is the direction of such shift that is more relevant to our study. The three-way relationship between factor intensity, factor endowment and growth can be explored more systematically by a regression model that fully utilizes the information in the data. Recall that in Equation 1, $a_3$ 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 a positive value when the dependent variable is the real output share and the industrial structure is optimally chosen. Ideally, Equation 1 can be estimated by each country and time period. The value $a_{3,j,t}$ of country *j* thus 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 resources are allocated optimally so that the industrial structure is fully consistent with the endowment level. This theoretical optimal $a_3^*$ is not very likely to be reached in a real economy, since in reality there are many factors that obstruct optimal resource allocation and the evolution of industrial structure. Then when the sizes of industries are prevented from evolving with capital accumulation, $a_{3,j,t}$ will be less than $a_3^*$. The smaller $a_{3,j,t}$ is, the less adaptive the industrial structure is to endowment change. In the extreme case when industrial development is to the opposite direction of capital endowment change, $a_{3,j,t}$ would be negative. It is a natural conjecture that the coherence level between industrial structure and capital endowment would have an impact a country's growth performance. The aggregate growth rate of country *j*, "$GROW_j$" can thus be modeled as a function of $a_{3,j,t}$. I assume that this relationship is linear and can be expressed as

$$GROW_{j,t} = f_1 + f_2 a_{3,j,t} \tag{4}$$

A high $a_{3,j}$ suggests that the industrial structure is more consistent with endowment level and the implied efficiency in resource allocation should be beneficial to economic growth. Therefore, $f_2$ is expected to be positive.

There are obviously important caveats to the functional form. First, it assumes that inefficiencies in resource allocation 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 this particular 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 it is reasonably safe to neglect the case of overly high $a_{3,j}$ in this sample.[15]

Second, the fixed relationship between economic growth and structural coherence specified in Equation 4 does not necessarily hold for every single period. First, the real economy experiences business cycle fluctuations for non-structural reasons. Second, the goal of the optimizing agents is not high growth for any single period, but life-time welfare maximization. However, Equation 4 means to describe the long-run relationship between growth and structural coherence. Thus despite the above mentioned qualifications, $f_2$ should still be positive if the observations are over an extended period of time.

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 1 by country and time. But the identification of $f_2$ is still achievable. Write Equation 4 as a function of $a_{3,j,t}$ and plug it back to Equation 1 with the real output share as the dependent variable:

$$\begin{aligned}\ln Y_{ij,t} = {} & d_1 + d_2 \mathrm{K}^x{}_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \times \mathrm{GROW}_{j,t} + d_3 \mathrm{K}^x{}_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} + d_4 \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \times \mathrm{GROW}_{j,t} \\ & + d_5 \mathrm{K}^x{}_{ij,t-1} \times \mathrm{GROW}_{j,t} + d_6 \mathrm{K}^x{}_{ij,t-1} + d_7 \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} + d_8 \mathrm{GROW}_{j,t} + d_9 \mathrm{Z}'_{ijt} + d_{10} \ln Y_{ij,t-1} + \zeta_{ijt}\end{aligned} \quad (5)$$

where $\ln Y_{ij,t}$ is the real output share of industry *i* in country *j*, $\mathrm{GROW}_{j,t}$ is country *j*'s 5-year GDP growth rate. To maintain the statistical soundness of the model, 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 also added to the regression equation.

The coefficient $a_3$ in Equation 1 is the counterpart of "$d_2 \mathrm{GROW}_{j,t} + d_3$" in Equation 5. According to our conjecture, the coefficient $d_2$, which is equal to $1/f_2$, is expected to be positive.

The estimation results are reported in Table 7. The 1st column presents the result with $K^x$ = overall capital intensity. Columns 2 to 4 are results when $K^x$ = ICT, structure and machinery intensity respectively. Column 5 reports the estimates when all three detailed types of capital are present in the estimation.

The three-way interaction terms "$\mathrm{K}^x{}_{ij,t-1} \times \mathrm{K}^x\_\mathrm{ENDW}_{j,t-1} \times \mathrm{GROW}_{j,t}$" are positive and significant at 1% level for all capital categories except for non-residential structure capital, which is positive but insignificant both when standing alone (column 3) and when combined with other types of capital (column 5). In general, the result confirms the hypothesis of a positive relationship between economic growth and structural coherence.

[15] As a robustness check, I also estimated equation 1, 2 and 5, leaving out data from Czech Republic and Slovenia, two former satellite countries of the Soviet Union. The results did not change very much. For the sake of space, those results are not reported in the paper.

**Table 7: Structural coherence and economic growth: basic estimates**

| | log(real output share) | | | | |
|---|---|---|---|---|---|
| | Overall capital | ICT | Structure | Machinery | ICT, Structure & Machinery |
| K ×K_ENDW × GROW | 0.1764***<br>(0.015) | | | | |
| ICT × ICT_ENDW × GROW | | 0.0861***<br>(0.0071) | | | 0.0629***<br>(0.0076) |
| STR × STR_ENDW × GROW | | | 0.0198<br>(0.0233) | | 0.0008<br>(0.0197) |
| MCH × MCH_ENDW × GROW | | | | 0.2466***<br>(0.022) | 0.0998***<br>(0.0227) |
| K × K_ENDW | -0.0232***<br>(0.0045) | | | | |
| ICT × ICT_ENDW | | 0.0216***<br>(0.0013) | | | 0.0213***<br>(0.0013) |
| STR × STR_ENDW | | | 0.0023<br>(0.0074) | | -0.014*<br>(0.0063) |
| MCH × MCH_ENDW | | | | 0.0079<br>(0.006) | 0.0122*<br>(0.006) |
| N | 8527 | 8502 | 8532 | 8532 | 8502 |

* 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; column 5 is the result when all three detailed types of capital are present in the regression. 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. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.001; **: p value<0.01; *: p value<0.05.

To get a sense of the magnitude of structural coherence's influence on growth, let's look at the three-way interaction term for the overall capital (column 1). Notice that $d_2$ = 0.176 implies the value of $f_2$ around 5.67. Suppose that we take the estimate for $a_3$, the coefficient for variable "K × K_ENDW" in equation 1 (the 1st column of table 5) to be the optimal value $a_3^*$ when industrial structure is fully in line with overall capital endowment. This is probably an under-estimate of the theoretical $a_3^*$ due to various frictions in real economy. The results from the equation 1 and 5 combined indicate a difference in 5-year aggregate output growth rate of 0.192 between the case of complete 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 35% of the gap between the growth rate of 1 percentile and of 99 percentile countries in the data.

# 4. Robustness

## 4.1 Using income share to measure factor intensity

In the baseline regressions I used the ratio of industry capital-x stock to real output ratio as the measure of industry capital-x intensity. To see how sensitive the main results are to the choice of measurement, here I use capital income share in industry value added as an alternative measure of capital intensity. In Table 8 and 9, 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.

Table 8 reports the regression results of Equation 2 with the alternative measure of capital intensity. Compared to the results in Table 5, the coefficients for the overall capital endowment and endowment growth interactions are generally smaller, but the significance levels do not change, except for the interaction "k × K_ENDW" in the employment share regression, which turns negative and insignificant. Among detailed categories of capital, compared to the baseline estimation the interactions for machinery capital endowment "mch × MCH_ ENDW" and endowment growth "mch × ΔMCH_ENDW" changed sign in the real output share regression; the interaction for structure capital str × STR_ ENDW turns positive in the nominal output share regression, which brings the directions of change for employment share and nominal output share the same for all types of capital. Other than the above differences, the estimates with the alternative capital intensity measure are fairly close to the baseline estimation when industry sizes are the dependent variables. When the labor income share is the dependent variable, the interaction terms for ICT capital turn positive; other types of capital retain the same signs as in the baseline regressions.

For the structural coherence and growth regression (Equation 5), as shown in Table 9 the three-way interaction terms are positive and significant for all types of capital except for non-residential structure, which is positive and significant when the estimation only includes one type of capital, but turns insignificant when all detailed types of capital are present in the estimation. All in all, changing the measure of factor intensity does not significantly change the regression results.

**Table 8: Capital endowments and structural change: alternative measure of capital intensity**

| | Dependent Variable | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Log (real output share) | | Log (employment share) | | Log (nominal output share) | | Log (labor income share) | |
| k × K_ENDW | 0.0161*** | | -0.0003 | | 0.0267*** | | -0.0645*** | |
| | (0.0017) | | (0.0014) | | (0.0021) | | (0.0027) | |
| ict × ICT_ENDW | | 0.0352*** | | 0.022*** | | 0.0215*** | | 0.0103*** |
| | | (0.001) | | (0.0008) | | (0.0012) | | (0.0017) |
| str × STR_ ENDW | | -0.0031 | | 0.011*** | | 0.0416*** | | -0.0199*** |
| | | (0.0036) | | (0.0031) | | (0.0044) | | (0.0054) |
| mch × MCH_ ENDW | | -0.0027 | | -0.0621*** | | -0.096*** | | 0.004 |
| | | (0.0046) | | (0.004) | | (0.005) | | (0.0075) |
| k × ΔK_ENDW | 0.1153*** | | 0.0828*** | | 0.2646*** | | -0.2494*** | |
| | (0.012) | | (0.0097) | | (0.0142) | | (0.0181) | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ict × ΔICT_ENDW | | 0.0467*** | | 0.0212*** | | 0.0247*** | | 0.0024 |
| | | (0.0027) | | (0.0024) | | (0.0033) | | (0.0046) |
| str × ΔSTR_ENDW | | 0.0908*** | | 0.1233*** | | 0.1291*** | | -0.0375 |
| | | (0.0137) | | (0.0119) | | (0.0165) | | (0.0206) |
| mch × ΔMCH_ENDW | | 0.0565*** | | -0.0222* | | -0.1408*** | | 0.0025 |
| | | (0.0099) | | (0.0087) | | (0.0112) | | (0.0156) |
| TFP growth | -0.0013*** | 0.0088*** | 0.0007*** | -0.0005** | 0.0002** | 0.0025*** | -0.0002* | -0.0065*** |
| | (0.0001) | (0.0002) | (0.000) | (0.0002) | (0.0001) | (0.0002) | (0.0001) | (0.0002) |
| N | 8773 | 8341 | 8773 | 8341 | 8773 | 8341 | 8766 | 8329 |

* The dependent variable is the log real output share of industry for column 1-2, the log employment share of industry for column 3-4, the log nominal output share of industry for column 5-6, and the log labor income share in industry value-added for column 7-8. The Arellano-Bond difference GMM estimator is used in all regressions. 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. $\Delta K^x$ _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<0.001; **: p value<0.01; *: p value<0.05.

**Table 9: Structural coherence and economic growth: alternative measure of capital intensity**

| | Log(real output share) | | | | |
|---|---|---|---|---|---|
| Variable | Overall capital | ICT | Structure | Machinery | ICT, Structure & Machinery |
| k ×K_ENDW × GROW | 0.1213*** | | | | |
| | (0.0316) | | | | |
| ict × ICT_ENDW × GROW | | 0.0511*** | | | 0.0421*** |
| | | (0.0063) | | | (0.0066) |
| str × STR_ENDW × GROW | | | 0.1381*** | | 0.0323 |
| | | | (0.0179) | | (0.0182) |
| mch × MCH_ENDW × GROW | | | | 0.5172*** | 0.4474*** |
| | | | | (0.0211) | (0.0216) |
| k × K_ENDW | 0.0045 | | | | |
| | (0.0066) | | | | |
| ict × ICT_ENDW | | 0.0256*** | | | 0.0247*** |
| | | (0.0012) | | | (0.0012) |
| str × STR_ENDW | | | -0.0436*** | | -0.0254*** |
| | | | (0.0042) | | (0.0042) |
| mch × MCH_ENDW | | | | -0.0791*** | -0.0885*** |
| | | | | (0.0054) | (0.0054) |
| N | 7913 | 8343 | 8343 | 8341 | 8341 |

* 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; column 5 is the result when all three detailed types of capital are present in the regression. 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. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.001; **: p value<0.01; *: p value<0.05.

## 4.2 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 aggregate, ICT and structure capital intensities. Meanwhile, more developed countries may have high endowments in both human capital and various types of physical capital. Therefore, I augmented Equation 1 with human capital intensity and the interactions between human capital intensity and different types of physical capital endowment.

Moreover, it is 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, I add to Equation 2 additional control terms 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 gross output ratio) and countries' aggregate output per worker.

Table 10 reports the regression results of Equation 2 for 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 industry size growth regressions, and negative in the labor income share regression. Although adding human capital controls make the coefficients of the main interaction term "K × K_ENDW" slightly lower in all four regressions, it does not impact the significance level of the coefficients. The sign and magnitude of the capital endowment growth interaction "K × ΔK_ENDW" are mostly unchanged.

The 2nd column under each explanatory heading reports results with controls of industry human capital, countries' GDP per worker (Y) and industries' degree of value-added (HighVA). The interaction terms "K × Y" and "HUM × Y" are positive and significant in most of the industry size growth regressions, except for "K × Y" in the employment share regression and "HUM × Y" in the real output share regression. The result suggests that

[16] I also estimated equation 1 for human capital endowment. The result is similar to Ciccone & Papaioannou (2009). Due to space limit, the result is not reported here.

capital intensive and human capital intensive industries are indeed larger in more developed countries, indirectly confirming the existence of the demand side structural change hypothesis. The coefficients for the interaction term "HighVA × Y" indicate that high value-added industries are bigger in higher-income countries in terms of nominal output, but not in real output. although the values of their coefficients are somewhat lower, the main interaction terms "K × K_ENDW" and "K × ΔK_ENDW" remain positive and significant in all industry size growth regressions, except for "K × K_ENDW" in the second nominal output share regression. In the labor income share regression, both sign and significance level of the two interaction terms remain basically unchanged.

**Table 10: Overall capital endowment and structural change: additional controls**

| Variable | Log (real output share) | | Log (employment share) | | Log (nominal output share) | | Log (labor income share) | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| K × K_ENDW | 0.0796*** | 0.0395*** | 0.0943*** | 0.0782*** | 0.1111*** | -0.0606*** | -0.0464*** | -0.0914*** |
| | (0.0087) | (0.0104) | (0.0082) | (0.0097) | (0.012) | (0.0144) | (0.0125) | (0.0158) |
| K × ΔK_ENDW | 0.3684*** | 0.359*** | 0.6997*** | 0.6267*** | 0.5264*** | 0.2914*** | -0.182*** | -0.2249*** |
| | (0.0214) | (0.0223) | (0.0163) | (0.017) | (0.026) | (0.0273) | (0.0335) | (0.0346) |
| HUM × K_ENDW | 0.0303*** | 0.0578*** | 0.1115*** | -0.1239*** | 0.1732*** | -0.0924*** | -0.0561*** | -0.0584** |
| | (0.0078) | (0.0117) | (0.0073) | (0.01) | (0.0094) | (0.0148) | (0.0138) | (0.0204) |
| K × Y | | 0.4302*** | | -0.0091 | | 0.4829*** | | -0.028 |
| | | (0.02) | | (0.0193) | | (0.0254) | | (0.0376) |
| HUM × Y | | 0.0116 | | 0.3439*** | | 0.3646*** | | -0.0052 |
| | | (0.0132) | | (0.0104) | | (0.0168) | | (0.0244) |
| HighVA × Y | | -0.2744*** | | 0.0344 | | 0.6401*** | | 0.2802*** |
| | | (0.0444) | | (0.037) | | (0.0534) | | (0.0827) |
| N | 8424 | 8424 | 8424 | 8424 | 8424 | 8424 | 8221 | 8221 |

* The dependent variable is the log real output share of industry for column 1-2, the log employment share of industry for column 3-4, the log nominal output share of industry for column 5-6, and the log labor income share in industry value-added for column 7-8. The Arellano-Bond difference GMM estimator is used in all regressions. 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 and country's real aggregate output per worker are also included as control variables. ***: p value<0.001; **: p value<0.01; *: p value<0.05.

Table 11 reports estimates of Equation 2 for ICT, non-residential structure and machinery capital with additional controls. Several things are worth noticing. First, the interactions between human capital intensity and ICT and machinery endowments have positive coefficients in all three industry size regressions, while the coefficients for "HUM × STR_ ENDW" are negative. The result may be due to the complimentary effect between human capital and technology capitals, or because of a positive correlation between technology capital endowments and human capital endowment.

Second, the interaction terms "ICT × Y" and "STR × Y" both have positive signs in all industry size regressions; yet the coefficients for "MCH × Y" are all negative. Since machinery intensive industries are mostly in the manufacturing sector, the result may be due to the de-manufacturing process that has been ongoing in most of the advanced economies in recent decades, partially caused by other factors such as international trade. However, the interactions between capital-x intensity and Y should be interpreted with caution. In some cases national income can be a better measure of capital endowment than capital stock itself, since the capital stock number may not take into account the quality or productivity differences of capital across countries of different development stages, which might be especially true for technology capital such as ICT and machinery. If this is the case, then the interaction terms between capital-x intensity and per worker aggregate output can also indicate the capital endowment effect on the dependent variable. The machinery interaction terms in the labor income share regression seem to manifest this logic: the main interaction term “MCH × MCH_ ENDW”, which is negative in the baseline regression, turns positive and significant when the interaction term “MCH × Y” is added, while the coefficient for the latter is negative and significant.

Thirdly, though the magnitudes of coefficients are slightly lower, most of the main interaction terms we are interested in have the same signs and significance level as in the baseline regressions, except for “STR × ΔSTR_ENDW” and “MCH× ΔMCH_ENDW”, which reversed signs in the regressions with only human capital controls. All in all, for the most part the capital endowment effect on industrial structural does not seem to be driven by other factors impacting the structural change process. And most of the endowment effect on capital-intensive industries’ labor income share also remains robust to additional controls.

**Table 11: Detailed capital endowments and structural change: additional controls**

| Variable | Log (real output share) | | Log (employment share) | | Log (nominal output share) | | Log (labor income share) | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| ICT × ICT_ENDW | 0.0304*** | 0.0157*** | 0.0145*** | 0.0107*** | 0.0185*** | 0.0034* | -0.0072*** | -0.0075** |
| | (0.0012) | (0.0015) | (0.001) | (0.0012) | (0.0015) | (0.0013) | (0.002) | (0.0023) |
| STR × STR_ ENDW | -0.0002 | -0.026** | 0.0693*** | 0.0641*** | -0.0511*** | -0.1847*** | -0.0738*** | -0.0627*** |
| | (0.0056) | (0.0085) | (0.0046) | (0.0072) | (0.0077) | (0.011) | (0.0115) | (0.0152) |
| MCH × MCH_ ENDW | 0.0162** | 0.0143* | -0.1006*** | -0.0758*** | -0.0562*** | -0.0281** | -0.0104 | 0.04** |
| | (0.0054) | (0.005) | (0.0045) | (0.0065) | (0.007) | (0.0099) | (0.0093) | (0.0129) |
| ICT × ΔICT_ENDW | 0.0596*** | 0.0448*** | 0.0343*** | 0.0263*** | 0.0336*** | 0.0216*** | -0.0268*** | -0.0258*** |
| | (0.0029) | (0.003) | (0.0025) | (0.0025) | (0.0036) | (0.0037) | (0.005) | (0.0051) |
| STR × ΔSTR_ENDW | -0.0735*** | 0.1501*** | -0.122*** | 0.3201*** | -0.1277*** | 0.081*** | 0.048** | -0.0476* |
| | (0.0106) | (0.0145) | (0.0082) | (0.0124) | (0.0131) | (0.0181) | (0.0174) | (0.0227) |
| MCH × ΔMCH_ENDW | 0.1501*** | -0.0811*** | 0.3081*** | -0.1141*** | 0.1039*** | -0.1082*** | -0.0533* | 0.0535** |
| | (0.0144) | (0.0107) | (0.0123) | (0.0083) | (0.0179) | (0.0133) | (0.0256) | (0.0176) |
| HUM × ICT_ENDW | 0.0192*** | 0.0113*** | 0.0358*** | 0.0252*** | 0.0355*** | 0.0159*** | -0.0217*** | -0.0286*** |
| | (0.0013) | (0.0017) | (0.001) | (0.0014) | (0.0014) | (0.0019) | (0.0021) | (0.0028) |
| HUM × STR_ ENDW | -0.0775*** | -0.0948*** | -0.0853*** | -0.1136*** | -0.0666*** | -0.1332*** | 0.0243 | 0.0132 |
| | (0.0072) | (0.0087) | (0.0059) | (0.0071) | (0.0083) | (0.0102) | (0.0127) | (0.015) |
| HUM × MCH_ ENDW | 0.0065 | 0.0142 | 0.0728*** | 0.085*** | 0.0885*** | 0.0752*** | 0.0597*** | 0.0694*** |
| | (0.0073) | (0.0079) | (0.0065) | (0.007) | (0.009) | (0.0098) | (0.0125) | (0.0138) |
| ICT × Y | | 0.1793*** | | 0.0628*** | | 0.0814*** | | -0.0058 |
| | | (0.0093) | | (0.0082) | | (0.0115) | | (0.0148) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| STR × Y | | 0.0819*** | | 0.0525*** | | 0.2488*** | | -0.0886*** |
| | | (0.014) | | (0.0118) | | (0.0176) | | (0.0228) |
| MCH × Y | | -0.0707*** | | -0.102*** | | -0.035** | | -0.0563*** |
| | | (0.0105) | | (0.0086) | | (0.0123) | | (0.0156) |
| HUM × Y | | 0.0641*** | | 0.1003*** | | 0.185*** | | 0.0292 |
| | | (0.0163) | | (0.0139) | | (0.02) | | (0.0273) |
| HighVA × Y | | -0.4273*** | | -0.2212*** | | 0.3032*** | | 0.6054*** |
| | | (0.05) | | (0.0406) | | (0.0609) | | (0.086) |
| N | 8394 | 8394 | 8394 | 8394 | 8394 | 8394 | 8191 | 8191 |

* The dependent variable is the log real output share of industry for column 1-2, the log employment share of industry for column 3-4, the log nominal output share of industry for column 5-6, and the log labor income share in industry value-added for column 7-8. The Arellano-Bond difference GMM estimator is used in all regressions. ICT, STR, MCH and HUM are capital intensities in information technology, structure, machinery 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 and country's real aggregate output per worker are also included as control variables. ***: p value<0.001; **: p value<0.01; *: p value<0.05.

Finally, let's look at the relationship between structural coherence and economic growth when additional controls are added. I augment estimation of Equation 5 with interaction terms involving human capital intensity, countries' GDP per worker, industries' degree of value added and TFP growth. Recall that the coefficients for interaction terms "HUM × $K^x$_ENDW" in Tables 10 and 11 are positive in the industry real output share regressions (except for "HUM × STR_ ENDW"). Thus it is natural to check if the coefficients for these human capital interaction terms are also related to aggregate growth, similar to the coherence effect described in section 3.2. It turns out that this conjecture is disconfirmed. Table 12A presents estimates of Equation 5 with human capital related controls. The three-way interactions "HUM × K_ENDW × GROW", "HUM × ICT_ENDW × GROW", and "HUM × STR_ENDW × GROW" all have negative coefficients with various significance levels. Only the term "HUM × MCH_ENDW × GROW" enters with a positive sign. On the other hand, the coefficients for the main interaction terms are very close to those in the baseline estimation. Thus the structural coherence' effect on aggregate growth is basically not impacted by adding human capital related factors.

**Table 12A: Structural coherence and growth: additional controls**

| | Log(real output share) | | | | |
|---|---|---|---|---|---|
| Variable | Overall capital | ICT | Structure | Machinery | ICT, Structure & Machinery |
| K ×K_ENDW × GROW | 0.1692*** | | | | |
| | (0.0167) | | | | |
| ICT × ICT_ENDW × GROW | | 0.1121*** | | | 0.0715*** |
| | | (0.0075) | | | (0.0084) |
| STR × STR_ENDW × GROW | | | 0.0012 | | 0.0329 |
| | | | (0.02) | | (0.0207) |
| MCH × MCH_ENDW × GROW | | | | 0.2386*** | 0.0899*** |
| | | | | (0.0239) | (0.0249) |
| HUM × K_ENDW × GROW | -0.1374*** | | | | |
| | (0.0363) | | | | |

| | | | | | |
|---|---|---|---|---|---|
| HUM × ICT_ENDW × GROW | | -0.0653*** | | | -0.0136 |
| | | (0.008) | | | (0.0097) |
| HUM × STR_ENDW × GROW | | | -0.1002*** | | -0.0614* |
| | | | (0.0194) | | (0.0252) |
| HUM × MCH_ENDW × GROW | | | | 0.0255 | 0.1113*** |
| | | | | (0.0274) | (0.0335) |
| N | 8424 | 8394 | 8424 | 8424 | 8394 |

* 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; column 5 is the result when all three detailed types of capital are present in the regression. 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. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.001; **: p value<0.01; *: p value<0.05.

Three additional factors that might influence the structural coherence effect are considered. First, results in Tables 10 and 11 suggest that development level does have certain impact on industrial structure: the capital intensive industries are generally bigger in higher-income countries. It is possible that aggregate growth is also affected by the degree to which the evolution of industrial structure aligns with a country's development stage. Second, the industry value added-development stage is an intuitively appealing explanation for structural change. Although the term "HighVA × Y" is not positive in the real output share regression, it is interesting to see if there is a linkage between the coefficient for this term and aggregate growth. Thirdly, the literature on allocative efficiency (Bartelsman, Haltiwanger & Scarpetta (2008), Arnold, Nicoletti & Scarpetta (2008)) suggests that growth is linked to whether resources are efficiently distributed to firms and industries with higher productivity. According to this proposition, a higher coefficient for industry TFP growth in the output share regression should also be beneficial to aggregate growth.

Table 12B presents estimates of Equation 5 with additional 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 interaction terms between different categories of capital intensity, countries' total output level and aggregate growth rate ($K^x$ × Y × GROW) do not have consistent signs, negative for overall capital and non-residential structure, and positive for ICT and machinery capital. The term "HighVA × Y × GROW" is mostly positive, except when put together with ICT capital interactions. The TFP interaction term "TFP_GROW × GROW" has positive and significant coefficients across all specifications, which indicates that efficient resource allocation in accordance with industry productivity does have a positive association with aggregate growth.

When $K^x$ is the overall capital, ICT capital or structure capital, the interaction term "$K^x$ × $K^x$_ENDW × GROW" remains positive as in the baseline regression; besides, the interaction for structure capital is now more significant than before. The three-way interaction for machinery capital becomes negative. However, notice that the newly-added control "MCH × Y × GROW" is positive and highly significant. Thus the change of sign for the term "MCH × MCH_ENDW × GROW" can be due to the fact that national income level is perhaps a better measure of machinery capital endowment than "MCH_ENDW". In sum, compared to the baseline results, except for the machinery capital, the main interaction terms between capital intensity, endowment and aggregate growth rate remain positive and significant after adding the additional controls. Therefore the linkage between structural coherence and economic growth does not seem to be a substitute for other effects.

**Table 12B: Structural coherence and growth: additional controls**

| | Log(real output share) | | | | |
|---|---|---|---|---|---|
| Variable | Overall capital | ICT | Structure | Machinery | ICT, Structure & Machinery |
| K ×K_ENDW × GROW | 0.1019***<br>(0.0166) | | | | |
| ICT × ICT_ENDW × GROW | | 0.0379***<br>(0.0092) | | | 0.0191*<br>(0.0092) |
| STR × STR_ENDW × GROW | | | 0.1734***<br>(0.032) | | 0.1266***<br>(0.0314) |
| MCH × MCH_ENDW × GROW | | | | -0.0958*<br>(0.0393) | -0.1849***<br>(0.0335) |
| K × Y × GROW | -0.0482***<br>(0.0063) | | | | |
| ICT × Y × GROW | | 0.1057*<br>(0.0413) | | | 0.1896***<br>(0.0513) |
| STR × Y × GROW | | | -0.5141***<br>(0.0669) | | -0.3317***<br>(0.0693) |
| MCH × Y × GROW | | | | 0.2027***<br>(0.0609) | 0.4264***<br>(0.0521) |
| HighVA × Y × GROW | 0.0728***<br>(0.0193) | -0.1689***<br>(0.0187) | 0.0558**<br>(0.021) | 0.027<br>(0.022) | 0.0442<br>(0.023) |
| TFP_GROW × GROW | 0.0062***<br>(0.001) | | 0.0086<br>(0.001) | 0.0028*<br>(0.0012) | 0.003**<br>(0.0011) |
| N | 8424 | 8394 | 8424 | 8424 | 8394 |

* 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; column 5 is the result when all three detailed types of capital are present in the regression. 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. 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. Lagged dependent variable, country's real aggregate output per worker, and industry 5-year TFP growth are also included as control variables. ***: p value<0.001; **: p value<0.01; *: p value<0.05.

## 5. Conclusion

This paper tests the endowment-based theory of industrial structural change proposed by studies such as Acemoglu & Guerrieri (2008) and Ju, Lin & Wang (2009), 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 would raise the output of the capital intensive industries relatively more, which process causes the industrial composition of an economy 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, then any arrangement that obstructs the structural change toward alignment with endowment fundamentals can be a detriment to economic growth.

This paper, using data of 27 industries from 15 countries, examines whether higher capital endowment is associated with larger sizes of capital intensive industries for overall capital and three detailed categories of capital, ICT, non-residential structure and machinery. For the overall capital, the real and nominal output share and employment share of capital intensive industries are significantly larger with higher initial period capital endowment and with faster capital accumulation. This result also applies to ICT capital and partially applies to machinery and structure capital. In addition, the labor income share of capital intensive industries is negatively associated with capital endowment and endowment growth for most types of capital. The result thus provides one way to understand the relationship between structural change and the declining trend of labor income share in many of the sample countries.

After confirming the impact of capital endowments on industrial structure, the paper tests 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 consistent with the country's endowment level in all types of capital. The results of the paper are mostly robust to alternative measures of capital intensity, to controls for other industry characteristics such as human capital and degree of value-added, and to controls for other determinants of structural change on both demand side and supply side.

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