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How the country's natural resource abundance affects the industrial growth? We argue that one of the transmission mechanisms is via the accumulation of country's high skilled human capital. In particular, we empirically investigate whether link between country's natural resource endowment and industry-level growth depends on industry human capital requirement. We show that in the 1980s and the 1990s, industrial sectors that are high-skilled labor intensive developed disproportionately slowly in countries with higher contribution of natural resource sectors to GDP. While low-skilled labor intensity did not differentiate industrial growth between resource rich and resource poor countries. Our findings are in line with the theoretical argument that deteriorative effect of natural resources on the development of industrial sector is a byproduct of the capital accumulation process in the resource abundant open economy that slows down the development of marginally high-skilled labor force compared to the resource poor economies.

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Каким образом изобилие природных ресурсов в стране влияет на промышленный рост? Мы показываем, что один из механизмов распространения связан с накоплением высококвалифицированного человеческого капитала в стране. В частности, мы проверяем эмпирически, зависит ли связь между ресурсным наделом страны и отраслевым ростом от требований отрасли к уровню человеческого капитала. Показано, что в 1980-х и 1990-х гг. промышленные сектора с интенсивным использованием высококвалифицированных трудовых ресурсов развивались диспропорционально медленно в странах с высокой долей ресурсных секторов в ВВП. В то же время интенсивность использования низкоквалифицированной рабочей силы не приводила к различиям в промышленном росте между странами с богатым и бедным наделом природными ресурсами. Результаты нашего исследования соответствуют теории: негативное воздействие на развитие промышленного сектора, связанное с изобилием природных ресурсов, является побочным продуктом процесса накопления капитала в открытой экономике с богатым наделом природными ресурсами, когда происходит замедление развития высококвалифицированной рабочей силы по сравнению со странами с бедным ресурсным наделом.

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1. Introduction[*, **]

The negative relation between the natural resource abundance and economic growth is well documented in the literature (Sachs, Warner, 1995, 1997, 1999 a, b, Sala-i-Martin, 1997; Doppelhofer et al., 2000). A number of theories were proposed to explain this negative link. The spectrum of issues raised in the literature ranges from the issues of currency appreciation in the era of high resource prices and the subsequent "Dutch disease" effects that deteriorate the development of industrial sector of the economy (Corden, Neary, 1984; Sachs, Warner, 1995) to the political economy problems associated with the numerous non-productive activities of economic agents provoked by the huge natural resource rents that undermine the institutional development of the economy and slow down economic development (Lane, Tornell, 1999; Auty, 2001).

One of the channels that the literature addresses deals with the link between human capital development and natural resource abundance (Leamer et al., 1999; Gylfason 2001). The argument is based on the idea that resource intensive sectors absorb national savings while creating only a few eminently qualified jobs which leads to lower incentive of the society to educate their citizens compare to the societies with lower abundance in natural resources. However, there is very little empirical research on this topic so far. For example, Gylfason (2001) using several proxies for human capital development such as a share of public expenditure on education in GDP, expecting years of schooling for females, gross secondary-school enrolment shows their significant negative bivariate correlation with the share of natural capital in national wealth in a cross section of 86 countries. Since the results of bivariate correlation can hardly be used as a basis for profound policy advice more rigorous empirical analysis of the human capital development explanation for the link between the natural resource richness and economic growth is called for.

Our paper addressed this question. We test the following theory proposed by Leamer (1987) and extended by Leamer et al. (1999). Leamer et al. (1999) consider physical capital accumulation in a small open economy with 3 factors of production: natural resources, labor and physical capital. The Hecksher — Ohlin features of the economy ensure the existence of cones of diversification within which

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for some range of factor endowments the product mix and equilibrium factor prices are uniquely determined and remain constant. Therefore the product mix within the cone corresponds to the level of factor endowments.

However the evolution of the economy from one cone to the next one requires a substantial upgrade of labor skills. Authors show that this transition could be problematic in resource rich economy as the increase in physical capital accelerates the substitution of labor in production and lowers the return to labor and human capital associated with it. This would not happen in resource poor economy as an increase in physical capital here will make labor more scarce factor of production and increase its payoff which in turn stimulates the investments in skills. Therefore one of the model results is that when we compare the resource rich economy to resource poor economy we expect the tougher deficit of the most skilled labor in the former one. Testable prediction of this result is that the industries which require sophisticated human capital inputs would be disadvantaged in resource rich countries relative to industries that technologically less dependant on the highly skilled labor. This disadvantage should disappear when we differentiate industries based on their demand for lower or average levels of human capital. These are the hypotheses that we test in our paper applying the now-standard methodology proposed by Rajan and Zingales (1998).

To test this prediction we construct the measures of industrial sectors' human capital requirements from data on the distributions of the levels of human capital of workers within US industries. Under the assumption that labor market and the corresponding market of human capital in U.S. are mobile we can use the observed distributions of human capital in the U.S. industrial sectors as a proxy for the demand of industries for lower and high levels of human capital. Assuming further that this demand is derived from production technologies and technologies spread fast across the world we can carry over the measures of industrial human capital demands to other countries. Then we examine whether industrial sectors that are relatively more skilled labor intensive develop disproportionately slowly in countries with higher contribution of natural resource sectors in overall GDP.

To reflect the heterogeneity of human capital and the fact that intensity of industries with respect to labor skills demand depends on the particular level of labor skills we construct several rankings of manufacturing industries for successive levels of human capital – from low skilled to high skilled ones.

For illustrative purpose consider the following example. According to our measures of high-skilled labor intensity industry Machinery has higher demand for very skilled labor relative to industry Metallurgy. According to our hypothesis we expect Machinery to develop relatively slowly than Metallurgy in countries that have more natural resources compared to resource poor ones. Let us compare the growth of these industries in three countries, Norway, Belgium, and Austria, over the period 1990—2000. Consistent with our arguments, in Norway, which is one of the richest natural resource countries, Machinery grew at a 4 percent lower annual real rate

than Metallurgy. In Belgium, which is among the poorest countries in terms of hydrocarbon production, Machinery grew at 2 percent higher rate than Metallurgy, and in Austria, which is among the countries with lowest share of primary export in overall GDP, Machinery grew at 1,5% higher rate than Metallurgy.

We implement a test of the theory in a cross-section of countries and industries. Our estimations show that when we measure industry skill intensity on the basis of the industry's demand for high-skilled labor (top deciles of human capital distribution) then we observe the significant systematic loss in growth rates of industries with higher demand relative to those with lower demand in countries rich in natural resources compared to resource poor countries. Moreover these estimated losses become insignificant as we use ranking of industries based on the demand for less or averagely sophisticated labor.

Our results show that natural resource abundance which is an exogenous characteristic of the country serves as an impediment for manufacturing sectors that depend on sophisticated human capital. At the same time our results suggest that there is no systematic effect of natural resource abundance on the growth of industrial sectors when we differentiate them based on their demands for lower skilled labor. This implies that one of the links between natural resource abundance and industrial growth could be through a human capital channel. Namely, natural resources could be a reason for slower accumulation of marginally skilled labor.

Moreover, our results emphasize that we need to be very careful in evaluating natural resource effects on human capital development. As we do not observe the deteriorating effect of resources on the differentiation of industrial growth when a measure of industries' human capital demand is based on low and average human capital levels it suggests that the aggregate measures of human capital development often cited in the literature could hardly be used to test the related hypothesis. More disaggregated data on countries' human capital levels are required to attain conclusions as our study indicates that it could be just the human capital in top deciles of distribution that is negatively affected by resource abundance.

What policy recommendations could we infer from this study? What are the policies that could turn the resource curse into the blessings?

While we used the example of Norway to illustrate the extent of the problem nevertheless it is the Norway that we usually refer to as the best example of the resource rich country that successfully oversteps the traps imposed by natural abundance. The state policy with respect to education is no exception. By law Norway's oil wealth is a public resource and the government takes in about 80% of oil rent through taxes and fees. Through the Stabilization Fund the government invests oil money in foreign securities in order to distribute oil revenues fairly between current and future generations while preserving current economy from overheating. Among the major current government concerns is an expenditure on education that substantially increases over time and the results are impressive: proportion of each cohort attending colleges and universities increased from 26% in 1980 to 62%

in 1997. Leamer et al. (1999) emphasize that an overall wealthy history of Scandinavian economies is a combination of education promotion and successful attraction of capital-intensive industries.

On contrary, the government policies in a number of developing countries with respect to savings and spending raise a lot of concerns. Farzin (1999) examines the optimal saving policy for a small exhaustible resource exporting economy and compares it with the actual saving rates of 14 oil- and other mineral-exporting economies. His results indicate that these countries substantially under save. This, first of all, prevents future generations from enjoying mineral rents and what is more important does not allow current generations to get easier access to modern education because of private and public under investment in human capital development. While in the world on average 64% of kids have access to secondary education this figure is 57% for OPEC countries. While world average spending on education is around 5% of the GNP, OPEC countries on average spend less than 4% (figures for 1997 from Gylfason (2001)).

Our study contributes to existing discussion on the transmission mechanisms of resource curse and emphasizes the importance of government policy with respect to investment in education to ensure the sustainable economic development of resource rich countries.

As far as the novelty of our result is concerned we need to mention that while establishing a significant and new result in the field our study benefited from the development of methodology and data analysis in other fields. The methodology we use was firstly implemented by Rajan and Zingales (1998) in their research about the effect of financial development on growth. The data on human capital level distribution of labor within industries of the U.S. come from Abowd, Lengermann, and McKinney (2003). And theoretical base of our study is mostly due to Leamer, Maul, Rodriguez, and Schott (1999) who developed the application of Heckscher-Ohlin model for the development path of resource rich economy.

In the paper we start with the discussion of theoretical reasoning that stimulated our research and the formulation of hypothesis in section 2, we describe the methodology in section 3, then in section 4 we proceed with the data description. In section 5 we present the results of our analysis and check their robustness. Section 6 concludes.

2. Theory of a human capital as a channel of resource abundance effect on industrial growth

The importance of human capital for development of resource rich countries is emphasized in a number of theoretical and empirical papers (Gylfason, 2001; Stijns, 2001; Bravo-Ortega, de Gregorio, 2005). Some authors evaluate the role of

human capital as the most important factor which accumulation will allow resource abundant country to overcome the problems with underdevelopment and, on the contrary, which under accumulation will prevent countries from industrial diversification (Leamer et al., 1999). Their argument is that resource intense sectors absorb national savings while creating only a few eminently qualified jobs. This leads to lower incentive of the society to educate their citizens compared to the societies with lower abundance in natural resources. The insufficient investment in human capital development in resource rich countries in turn prevents them from attaining higher growth rates.

Leamer et al. (1999) analyze this kind of argument in the traditional trade framework. The countries are modeled as Heckscher — Ohlin small open economies. The factor endowment of a particular country at any point in time determines its product mix and returns to factors. The product mix and the factor returns remain constant within some range of factor endowments which is referred to as cone of diversification. Along the time the country accumulates the physical capital stock and switches from one cone of diversification to another with the corresponding changes in product mix. The authors distinguish three productive factors: labor with associated human capital, natural resources and physical capital. The relative endowments of these factors determine the evolutionary paths of the economy. In the world of free trade according to the principle of comparative advantage the countries abundant in natural resources choose to produce a relatively natural-resource-rich mix of tradable goods. Along the development paths the speed of capital accumulation will depend on the relative return to capital. This, in turn, determines the time the countries switch from one cone of diversification to another, from lower capital-intensive mix to higher one. Within a cone of a diversification, where the product mix is fixed, changes in factor supply have no effect on factor prices and returns. The moment of switch from one cone to another is accompanied by the decline in price of capital because of its easier availability.

The development path of the resource rich country can be presented in the following way. The most underdeveloped countries develop labor-intensive extraction industries. Initial capital accumulation leads to more capital-intensive extraction, which comes with the decline in wages of primitive labor since capital accumulation is designed to economize on the labor input. With further capital accumulation new more capital-intensive ways of utilizing natural resources develop — resource-based manufacturing. Finally, when capital-accumulation is substantial the resource rich country produces sophisticated and capital-intensive manufactures such as machinery and chemicals.

The problem that comes along this evolutionary path and at some point can prevent the further development of the country is that the new more capital-intensive technologies require more skilled labor. However as pointed above the availability of natural resources makes the sufficient accumulation of skills and human capital very unlikely as the return to labor declines as economy accumulate physical capital which is not the case in countries with insignificant amount of resources where capital accumulation makes labor and correspondingly human capital more critical factors of production. The underdevelopment of skills can prevent the country from switching into new more advanced product mixes and lock the country in the previous cone of diversification.

We can summarize the human capital channel that transmits resource abundance to industrial development in the following way. The existence of natural resources in an economy provokes the decline in the return to labor and subsequently to human capital as physical capital stock accumulates in the economy. This prevents the development of new more sophisticated industries as there is no enough skilled labor. In other words, the resource rich economy faces a trap of skilled labor underdevelopment.

An important feature of the model is that in the world of global trade the movement from natural resource extraction to capital and resource intensive manufacturing requires a substantial upgrading of the human capital but when most of savings are generated by a few resource-owners it may be difficult for the economy to transfer those savings in the sophisticated human capital assets.

When we apply the model findings to actual industrial development across the countries we could expect that those industrial sectors which technologies are more intensive in sophisticated human capital will be in disadvantage in economies rich in natural resources. The model prediction is that while there are enough workers with average skills in the resource rich economy it is the insufficiency of marginally high skills in the resource rich economies that prevents the successful development of new industries.

In what follows we focus our attention on the development of manufacturing sectors. We formulate the hypotheses we intend to test in the following way.

First, we expect that the difference in growth rates between industries with higher and lower demand for high skilled labor is lower in resource rich country compared to resource poor country. At the same time we expect that there should not be the differentiated effect of resource abundance on industry growth based on industry's demand for average and lower skilled labor.

3. Methodology

To test the hypotheses we need to apply cross country analysis to find out whether there is a significant disadvantage of human capital intensive industries in resource rich countries compared to resource poor countries. We follow the methodological approach of Rajan and Zingales (1998). They study the effect of financial

market underdevelopment on the industries' growth. The advantage of the approach is that it allows overcoming some of problems researchers usually face while doing empirical cross-countries growth studies.

In regression equation the dependent variable is the average annual real growth of industry i in country k over the period 1980—1990. We construct two measures of human capital demand of industry i to approximate industry's intensity with respect to low skilled labor, hc_i^{low}, and industry's intensity with respect to high skilled labor, hc_i^{high}. For each country k we have a measure of country resource richness, res_k.

In order to correct for industry and country effects we include industry and country dummies. Following Rajan and Zingales (1998) besides the interaction term we include only one country-industry variable which is industry's i share in country's k manufacturing value added at the beginning of the period under study, that is, in 1980, X_{ik}. Following Solow (1956) argument we expect the estimated coefficient at this variable to be negative.

For each level of human capital h we estimate the following specification.

$$Growth_{i,k} = Constant + \alpha_k + \beta_i + \delta \cdot X_{ik} + \gamma^{low} \cdot HC_i^{low} \cdot Res_k + \\ + \gamma^{high} \cdot HC_i^{high} \cdot Res_k + \varepsilon_{i,k}. \qquad (1)$$

This specification allows us to perform difference in differences estimations, that is, to evaluate the difference in growth between industries within countries and compare these differences across countries. The inclusion of country and industry dummies helps us to deal with country and industry level omitted variables.

Controlling for industry and country effects we expect to find that

1) the estimated coefficient at the interaction term between high skilled human capital intensity and resource richness, γ^{high}, is significant and negative;

2) the estimated coefficient at the interaction term between low skilled human capital intensity and resource richness, γ^{low}, is insignificant;

3) the estimated coefficients at interaction terms, γ^{high} and γ^{low}, are statistically different.

4.Data

4.1. Human capital intensity of industries

Each industry has specific requirements for the proportion of labor force of a particular level of human capital. These requirements are derived from the technological process the industry utilizes. While the observed human capital intensity of the industries is the result of the equilibrium on the human capital market of the economy we could assume that this market is perfectly mobile within economy and firms in all industries face the same supply of human capital of particular level. In this setup the differences between the actual distributions of human capital within industries will reflect the differences in the industries' human capital requirements. Moreover we assume that the differences in these requirements are persistent over time, at least in short and medium run, and across countries as well.

To justify our assumption of the persistency of industries' human capital intensities across countries we limit our study to manufacturing industries that nowadays employ similar technologies across the world. This allows us to assume that if one manufacturing sector in the United States is more human capital intensive than another then this ranking remains valid for other countries as well.

To deal with the problem of the persistence of ranking over time we rely on broadly defined manufacturing industries. We use data for 3-digit ISIC industrial decomposition (2-digit SIC) which divides all manufacturing in 28 sub sectors. While we could expect that for some quite narrowly defined industries the human capital intensity ranking can change over the period of 10 years the ranking of sufficiently aggregated industries should be more stable.

Abowd et al. (2003) estimate the human capital index for each of 68 millions of U.S. workers (which covers 45% of U.S. labor force) that were surveyed within Longitudinal Employer — Household Dynamics (LEHD Program's individual, employer, and employment history databases). As this database matches workers with their respective firms the authors were able to control for firms' wage strategy and to single out and to measure the human capital index of the individual which includes both formal education and other individual characteristics. Based on these indexes the overall distribution of U.S. workers' human capital skills was constructed. The whole range of measured human capital was divided into 10 equal deciles. Then each individual human capital index was placed into the industry where the firm she employed in belongs to. This allows them constructing the comparable human capital level distributions of labor within U.S. industries. Using this kind of data we are able to have not just the only ranking of industries based on the demand for the average level of human capital but also to exploit the sensitivity of the result to the demand for different levels of human capital.

The authors perform the study for two years — 1992 and 1997. As we will point out below we are interested in the earliest possible estimation for U.S. economy in order to carry over the proxy for demand to other economies. So we base our analysis on the results of Abowd et al. (2003) for 1992 industrial distribution of U.S. human capital. Authors present the distribution of human capital for 2-digit SIC (Standard Industrial Classification) decomposition of U.S. economy. However this classification can be converted to ISIC (International Standard Industrial Classification) economy decomposition for which the comprehensive cross-country industrial database exists only with some losses. So some part of data suitable for our study was lost during the conversion.

Based on the distribution of industry demand for human capital we constructed nine measures of industry human capital demand depending on the level of human capital in question, hc^n, as the sum of shares of labor force in deciles of human capital distribution above and within decile n, $n = 2, ..., 10$. For each n this sum approximates the probability that the skill of the worker hired by the average firm in the industry is above the level that corresponds to the level of skills in decile n. Therefore for each level of human capital we define the human capital intensity of an industry as the probability that the worker hired by the industry will have the skills above or equal to this level of human capital. An increase in our measure of industry's intensity for a particular level of human capital implies an increase in the probability that the industry demands the worker with the skills above this level of human capital.

Depending on the value of n we are able to rank industries based on the demand for human capital of various levels. The ranking of industries based on the share of n top deciles of l human capital level distribution reflects the relative position of the sector in the demand for low and average human capital if $n = 2, 3, 4, 5$ and very skilled human capital if $n = 6, 7, 8, 9, 10$.

To test the hypotheses applying the basic regression equation (1) for each industry i we use two measures of human capital intensity, the extreme ones:

$$hc_i^{low} = hc_i^2 \equiv$$

$$\equiv \sum_{n=2}^{10} share\ of\ labor\ force\ in\ decile\ n\ of\ human\ capital\ distribution\ in\ industry\ i,$$

$$hc_i^{high} = hc_i^{10} \equiv share\ of\ labor\ force\ in\ 10^{th}\ decile\ of\ human\ capital\ distribution.$$

For robustness check we also perform analysis for other measures of industries' intensity for low skilled labor: $hc_i^{low} = hc_i^3$, $hc_i^{low} = hc_i^4$, $hc_i^{low} = hc_i^5$.

Table 1 shows the ranking and the corresponding measure of human capital demand of U.S. industries based on nine measures of human capital demand. We focus only on those industries that we later use in our sample given the availability of the relevant growth data. Table 1 reveals that while some industries are always in the top (Petroleum and Coal Products) or bottom (Food Products) there is an up and down movement of industries in the middle of table. Therefore it provides us with sufficient dispersion of the rankings which is the prerequisite for revealing the expected results empirically.

To use U.S. industrial human capital distribution as a proxy for other countries relative industrial demand for human capital we need to do the following assumptions.

1. We assume that the human capital intensity of industry is derived from the technology of the industry. To the extent that technologies nowadays are easily transferable across the world by trade and multinationals then the use of U.S. data

for ranking of industries outside U.S. is justified. As there is a number of developing countries in our dataset and we expect some lag to exist in technology transfer from the most developed country in the world to less developed ones then we use the earliest available data on ranking of U.S. industries with respect to human capital intensity which is data for 1992.

2. We assume that labor market and the corresponding market of human capital in U.S. are mobile, frictionless and competitive. Then we can use the observed distribution of human capital in U.S. industrial sectors as a proxy for the relative demand of industries for various levels of human capital.

4.2. Other industrial characteristics

Data on average annual real growth rates of manufacturing sectors are calculated based on nominal value added data from UNIDO (United Nation Industrial Development Organization) database for 3-digit ISIC codes (Rev. 2) that were corrected by GDP deflator from WDI (World Development Indicators) database. Share of sector in total manufacturing value added also comes from UNIDO database.

Table 3 provides summary statistics of all variables used in regression analysis.

4.3. Data on countries

The only country characteristic used in our analysis is the measure of its natural resource abundance. There is no consensus in the literature regarding the best measure of resource abundance. Following the empirical strategy of Sachs and Warner (1995, 1997) we employ two basic measures of resource abundance.

First, we focus on raw hydrocarbon production of the economy as a share of country's GDP. For robustness check we also use oil production as a share of GDP.

We choose production of hydrocarbons instead of the estimation of countries' storage of hydrocarbons as it is suggested by Gylfason (2001) because it is the extent of existing extraction production that is of interest to us. The theoretical justification of the hypothesis we intend to test comes from the transmission mechanism that argues that the higher is interaction between the existing extraction industry and capital accumulation the lower is return to labor and slower is an accumulation of human capital. So it is the measure of existing production rather than storage of resources that should be used in our test.

We focus on hydrocarbons because the comprehensive historical database for hydrocarbon production across the world is available from BP Statistical Review of World Energy. For robustness check we calculate these values for 1980 and average value over the period 1980—1990 as well.

As a second measure of natural resource abundance we use the share of primary export in country's GDP in 1980. In primary export we include raw agricultural, fuel and mineral exports. We construct this measure based on data from WDI dataset. So by construction the second measure is more "diversified" in terms of sectors that contributed into this measure.

Given our theoretical arguments and the fact that countries with quite different natural resource structures could have similar index of natural resource abundance estimated by primary export share we expect this measure to be noisier in terms of expected result. We will argue more on this issue later while discussing results.

Both measures of natural resource abundance are tabulated in table 2. Since the industrial demand for human capital is obtained using U.S. industries demand for labor we drop U.S. from our cross-country analysis.

5. Natural resource intensity and growth

5.1. Results: regression with the share of hydrocarbon production in GDP as a measure of resource abundance

Table 4 reports the results of regression (1) for the period of 1980—1990. In this specification we rely on share of hydrocarbon production in GDP in 1980 as a proxy for resource abundance. While estimating the regression we control for industries' and countries' specific effects which we do not report in the table.

The first line reports the coefficient at the share of the industry in total manufacture value added. It is always negative and significant. Thus, controlling for initial conditions we obtain the expected result that industries of smaller size grow faster than more developed ones.

The coefficients of interest to us are the ones at the interaction terms between industry's human capital intensities and country's resource abundance. In column (1) — (4) we report estimation results for four different proxies for low-skilled labor industry intensities, $hc_i^{low} = hc_i^2, hc_i^3, hc_i^4, hc_i^5$, while keeping the same proxy for high-skilled labor industry intensity $hc_i^{high} = hc_i^{10}$.

The negative and statistically significant coefficients at the interaction term between the country's natural resource abundance and high-skilled labor intensity in all four columns (1) — (4) indicate that we can not reject the hypothesis that the natural resource abundance serves as an impediment for the growth of industries that intensive with respect to high skilled labor relative to industries less dependent on high skilled labor. This result confirms our first hypothesis.

The insignificant coefficients at the interaction term between the country's natural resource abundance and low-skilled labor intensity in all four columns indicate that we can not reject the hypothesis that the natural resource abundance does not have differentiated effect on industries based on their intensity to low-skilled labor. This result confirms our second hypothesis.

As indicated by F-test, the effect of resource abundance interacted with low-skilled labor intensity on the industrial growth is statistically different at 10% level of significance from effect of abundance interacted with high-skilled labor intensity. This result is confirmed for the first three measures of low-skilled labor intensity and rejected for the fourth one as reported in column (4) in table 4. Therefore this confirms our third hypothesis at 10% level of significance.

We perform the same analysis keeping only those observations for which the average growth rates over 1980—1990 are positive. We expect that this should improve the significance of our results because according to the theory the reason for the negative effect of resource abundance on industrial growth is the insufficiency of high skilled labor in resource rich countries. Therefore it is reasonable to expect that it would be growing industries that face high-skilled labor constraint than declining industries. Columns (5) — (8) reports the results of estimation of equation (1) for four measures of low-skilled labor intensity. Again the results support all three hypotheses and the difference between the effects of resource abundance on industrial growth differentiated by low-skilled labor and high-skilled labor intensities becomes significant at 5% level.

To estimate the magnitude of losses in real growth of industries that intensive with respect to high-skilled labor in resource rich countries we compare two industries, one from the 25^{th} percentile of high-skilled labor intensity (Food and Beverages) and one from the 75^{th} percentile of the same distribution (Machinery), in two countries, one from the 25^{th} percentile of resource abundance (France) and one from the 75^{th} percentile of the same distribution (UK). The estimated coefficient then implies that Machinery should grow 0,8% slowly annually in real terms than Food and Beverages in UK than compared to France. This is a substantial loss in growth rate as the average annual real growth in the sample is 2,2%.

The obtained results are consistent with our expectations. As the Leamer et al (1999) model suggests there would not be problem with the supply of human capital that the economy needs to produce the prevalent product mix. However the development of new industries and products that requires new, that is higher, level of skills will be difficult because of lower return to labor in resource rich countries as compared to resource poor countries. So as we move from the measure of low-skilled labor intensity to the high-skilled labor intensity we observe the increase in the negative effect of resources on industrial growth.

5.2. Robustness of the results

Other measures of resource abundance
Share of primary export in GDP

Table 5 reports the estimation of regression (1) where the share of primary export in GDP is used as a proxy for resource abundance. First four columns refer to the estimations based on the full sample while last four columns refer only to estimations based on observations with positive real average growth.

Again we skip the coefficients at countries' and industries' dummies and report only the coefficients at industry-country variables.

As in the previous case the coefficients at initial share of the industry in total manufacture value added are consistent with the Solow convergence argument.

The estimated coefficients at the interaction term between the measure of high-skilled labor intensity and resource abundance while being negative in all columns (1) — (8) are not significant. F-test indicates that the difference between interaction of resource abundance with low-skilled labor intensity and the high-skilled one is also insignificant. The results seem to reject at least two out of three hypotheses that we test. Can we explain these results from the point of theoretical backup of our approach?

Let us consider the example. Suppose two countries have similar measures of resource abundance based on the share of primary export but one country is an exporter of agriculture and does not have any mineral or fuel production in the economy at all and the other country has only oil extraction and no agriculture at all. If the human capital channel of resource curse works through the interaction between the capital accumulation and the natural resource sector then the nature of resource sector becomes important. Namely, the scale of labor substitution due to physical capital accumulation which leads to decline in return to labor and lower incentives to invest in human capital is determined by the production technologies in resource sectors and would be different for agriculture and oil extraction. We should expect that the more homogeneous in terms of technological composition is the measure of resource abundance the more significant should be the estimated results. The more diversified is the measure of resource abundance the more noisy would be the results.

Therefore, while results reported in table 5 do not provide a strong support for our hypothesis, nevertheless they do not contradict to it. This result emphasizes the importance of proper proxy for resource abundance that could be exploited to test the hypotheses.

To check further the robustness of obtained results we use other proxies for natural resource abundance such as the oil production in GDP in 1980, average share of hydrocarbon production in GDP over 1980—1990, etc., and the estimated results are in line with the reported in table 4. Table 6 reports the estimation results based on the share of oil production in GDP in 1980 as a proxy for natural resource abundance. The estimated coefficients and F-test do not reject all three hypotheses and the level of confidence is higher when we limit the sample to the growing industries only.

Then we construct new dataset, now for the time period from 1990—2000, to check the consistency of our findings. The results of estimation of the equation (1) on new dataset is reported in table 7 where we use the average production of hydrocarbons over 1990—2000 as a proxy for countries' resource abundance.

The statistical significance of the coefficients at interaction term between high-skilled labor intensity and resource abundance and value of F-tests reported in columns (1) — (8) confirm all three hypotheses. That is, the hydrocarbon resource abundance remained an impediment for the development of high-skill intensive industries over the period 1990—2000 despite the fact that during this period the hydrocarbon raw materials were priced relatively low on the world market. The effect becomes even stronger. The estimated coefficient from column (1) implies that Machinery (the 75^{th} percentile of high-skilled labor intensity distribution) should grow 4,7% slowly annually in real terms than Food and Beverages (the 25^{th} percentile of the same distribution) in Canada (the 75^{th} percentile of resource abundance distribution) than compared to Sweden (the 25^{th} percentile of the distribution). This is a great loss in growth rate as the average annual real growth in the sample is 5,4%.

The estimated increase in the magnitude of the effect is consistent with the theory of transmission effect from resource abundance to the development of skill intensive industries. The theory implies that the past under accumulation of marginally skilled human capital in the era of high hydrocarbon prices will continue to affect the growth of high-skilled intensive industries after the fall in the prices as it is impossible for the economy to progress rapidly with human capital accumulation. At the same time if we use current rather than past data to measure the resource abundance of the economy then we should expect the increase in the estimated losses of high skilled intensive industries because current lower prices of resources will underestimate the accumulated lag in human capital development. We confirm this by estimating equation (1) over the period 1990—2000 using average hydrocarbon production over 1984—1990 as a proxy for country's resource abundance.

The use of various proxies for natural resource abundance and various time intervals reveal the importance of further study of the effects of particular type of natural resources on industrial growth and its dynamics over time. We expect that the extent of deteriorative effect of a particular type of natural resources on the growth of high-skilled intensive industries positively depends on the past rent generated in the resource sector and the expected price of this resource in future.

6. Conclusion

We show that industries that require a large share of high-skilled labor grow slowly than less high-skill intensive industries in resource rich economies compared to resource poor countries. We do not find intensity measured on the share of low-skilled labor to be an important factor to differentiate industrial growth between resource rich and resource poor countries.

Our findings are consistent with the argument developed in theoretical literature that deteriorative effect of natural resources on the development of industrial sectors could be the byproduct of the capital accumulation process in the resource abundant open economies that undermines the development of high skilled labor force. As a sustainability of economic growth is conditional on the development of innovative high skilled industries then the natural resources pose a real threat to the long-run industrial development of resource rich countries. This problem becomes even more dramatic if we take into account the irreplaceable nature of most natural resources and it emphasizes the need of proper government policy to address the threat. And not just spending on general education is important but special measures to ensure the development of very sophisticated and professional human capital need to be implemented.

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Table 1. Distribution of employees by their human capital level in U.S. industries in 1992

	Manufacturing sector	**ISIC**	**Share of employees with human capital whose level is in deciles from …-to….** 2—10	3—10	4—10	5—10	6—10	7—10	8—10	9—10	10
			hc^2	hc^3	hc^4	hc^5					hc^{10}
1	Petroleum and coal products	354	91.7	84.7	77	68.1	58.1	47.4	36.4	25.6	15
2	Machinery, except electrical	382	90.5	82.6	74.4	65.6	56.1	46	35.6	24.8	13.5
3	Iron and steel + Nonferrous metals	371 + 372	89.3	78.7	67.5	56.1	45	34.7	25.5	17.1	9.2
4	Transport equipment	384	88.2	77.4	66.7	56	45.4	35.2	25.7	17	8.9
5	Paper and products	341	88	77	66.3	55.8	45.5	35.9	27.1	19	11
6	Printing and publishing	342	87.7	78.8	69.8	60.3	50.5	40.7	31.1	21.6	12.1
7	Wood products, except furniture	331	87.3	76.8	66.5	56.4	46.6	37.2	28.2	19.5	10.6
8	Electric machinery	383	86.1	74	63.2	53.3	44.1	35.6	27.7	19.9	11.4
9	Textiles	321	85.3	74.4	65.1	56.5	48.2	40	31.7	22.9	12.9
10	Food products + Beverages	311 + 313	83.7	71.9	61.5	51.6	42	33	24.8	17.3	9.8
11	Other manufacturing products	390	81.7	68.4	57.2	47	37.8	29.6	22.2	15.4	8.9

Four proxies for industry intensity with respect to low skilled labor, hc^{low}

Industry intensity with respect to high skilled labor, hc^{high}

Table 2. Natural resource abundance across countries

		Share of primary export to GDP, 1980	Share of hydrocarbon production to GDP, 1980	Share of oil export to GDP, 1980
1	Japan	0	0.000	0.000
2	Singapore	0	0.000	0.000
3	Bangladesh	0.02	0.013	0.000
4	India	0.02	0.015	0.014
5	Korea	0.02	0.000	0.000
6	Germany	0.03	0.004	0.000
7	Italy	0.03	0.008	0.001
8	Spain	0.03	0.000	0.000
9	Turkey	0.03	0.000	0.000
10	Austria	0.04	0.000	0.000
11	France	0.04	0.000	0.000
12	Israel	0.04	0.000	0.000
13	Brazil	0.05	0.017	0.016
14	Pakistan	0.05	0.037	0.000
15	Portugal	0.05	0.000	0.000
16	Sweden	0.05	0.000	0.000
17	Greece	0.06	0.000	0.000
18	United Kingdom	0.06	0.050	0.039
19	Finland	0.08	0.000	0.000
20	Mexico	0.08	0.161	0.139
21	Colombia	0.09	0.079	0.060
22	Jordan	0.09	0.000	0.000
23	Denmark	0.1	0.001	0.001
24	Morocco	0.1	0.000	0.000
25	Australia	0.11	0.046	0.034
26	Philippines	0.11	0.000	0.000
27	South Africa	0.11	0.000	0.000
28	Canada	0.12	0.125	0.081
29	Egypt	0.12	0.361	0.348
30	Belgium	0.13	0.000	0.000
31	Costa Rica	0.14	0.000	0.000
32	Kenya	0.16	0.000	0.000
33	Zimbabwe	0.17	0.000	0.000
34	Chile	0.18	0.000	0.000
35	Peru	0.18	0.123	0.123
36	New Zealand	0.19	0.007	0.000
37	Netherlands	0.2	0.068	0.000
38	Sri Lanka	0.21	0.000	0.000
39	Norway	0.22	0.165	0.102
40	Nigeria	0.3	0.415	0.411
41	Venezuela	0.3	0.469	0.436
42	Malaysia	0.42	0.141	0.141

Table 3. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Industry's real annual growth, 80—90	417	0.023	0.087	–0.447	0.328
Initial share of industry in GDP, 1980	417	0.022	0.028	0.000	0.224
Measures of resource dependence					
Share of primary export to GDP, 1980	42	0.105	0.090	0.000	0.420
Share of oil production in GDP, 1980	42	0.048	0.106	0.000	0.436
Share of hydrocarbon production in GDP, 1980	42	0.057	0.112	0.000	0.469
Measures of Human Capital Intensity					
Median of Industry's Human Capital Distribution	11	5.934	0.333	5.554	6.757
Share of labor force in upper deciles of human capital distribution from …					
2 to 10	11	0.871	0.026	0.817	0.917
3 to 10	11	0.765	0.041	0.684	0.847
4 to 10	11	0.665	0.049	0.572	0.770
5 to 10	11	0.567	0.053	0.470	0.681
10^{th} decile	11	0.111	0.018	0.089	0.150

Table 4. Industry Growth and Demand for Human Capital of Various Levels, 1980—1990.
Measure of resource abundance - share of hydrocarbon production to GDP, 1980

Dependent variable: Industry's Real Annual Growth, 1980—1990								
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of industry in total manufacturing value added, 1980	−0.939	−0.939	−0.939	−0.939	−0.218	−0.219	−0.219	−0.219
	(0.324)***	(0.323)***	(0.323)***	(0.323)***	(0.101)**	(0.101)**	(0.101)**	(0.101)**
Interaction term: (Share of hydrocarbon production to GDP, 1980) * (industry intensity with respect to human capital of ...)								
				proxy for low-skilled labor intensity				
	hc^2	hc^3	hc^4	hc^5	hc^2	hc^3	hc^4	hc^5
low skills	0.786	0.353	0.311	0.332	0.495	0.441	0.534	0.687
	(1.125)	(0.783)	(0.728)	(0.777)	(0.677)	(0.522)	(0.529)	(0.585)
high skills	−4.518	−4.439	−4.549	−4.717	−3.028	−3.284	−3.703	−4.25
	(2.017)**	(2.185)**	(2.397)*	(2.719)*	(1.205)**	(1.287)**	(1.448)**	(1.679)**
Industries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417	417	417	417	304	304	304	304
R-squared	0.44	0.44	0.44	0.44	0.57	0.57	0.57	0.57
F-test: $\gamma^{low} = \gamma^{high}$	3.7	3.09	2.73	2.27	4.76	5.23	5.28	5.21
P- value of F-test	0.06	0.08	0.1	0.13	0.03	0.02	0.02	0.02
Robust standard errors in parentheses								
* significant at 10%; ** significant at 5%; *** significant at 1%								

Columns (1) — (4) — equation (1) is estimated on full sample, columns (5) — (8) — only on those observations with positive average growth rates over the period.

Table 5. Industry Growth and Demand for Human Capital of Various Levels, 1980—1990.
Measure of resource abundance — share of primary export in GDP, 1980

Dependent variable: Industry's Real Annual Growth, 1980—1990								
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of industry in total manufacturing value added, 1980	−0.971	−0.968	−0.966	−0.966	−0.191	−0.197	−0.199	−0.202
	(0.323)***	(0.322)***	(0.322)***	(0.322)***	(0.106)*	(0.105)*	(0.104)*	(0.104)*
Interaction term: (Share of primary export in GDP, 1980) * (industry intensity with respect to human capital of ...)								
				proxy for low-skilled labor intensity				
	hc^2	hc^3	hc^4	hc^5	hc^2	hc^3	hc^4	hc^5
low skills	−0.673	−0.393	−0.237	−0.178	1.031	0.643	0.581	0.535
	(1.537)	(1.038)	(0.959)	(1.009)	(1.173)	(0.84)	(0.803)	(0.855)
high skills	−2.778	−2.714	−2.808	−2.858	−0.021	−0.165	−0.391	−0.488
	(2.689)	(2.756)	(2.916)	(3.257)	(1.943)	(1.947)	(2.05)	(2.314)
Industries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417	417	417	417	304	304	304	304
R-squared	0.44	0.44	0.44	0.44	0.56	0.56	0.56	0.56
F-test: $\gamma^{low} = \gamma^{high}$	0.4	0.52	0.56	0.47	0.23	0.13	0.16	0.13
P- value of F-test	0.53	0.47	0.46	0.5	0.64	0.71	0.69	0.72
Robust standard errors in parentheses								
* significant at 10%; ** significant at 5%; *** significant at 1%								

Columns (1) — (4) — equation (1) is estimated on full sample, columns (5) — (8) — only on those observations with positive average growth rates over the period.

Table 6. Industry Growth and Demand for Human Capital of Various Levels, 1980—1990. Measure of resource abundance – average share of hydrocarbon production in GDP, 1980—1990

Dependent variable: Industry's Real Annual Growth, 1980—1990								
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of industry in total manufacturing value added, 1980	–0.94	–0.94	–0.939	–0.939	–0.218	–0.218	–0.218	–0.218
	(0.322)***	(0.322)***	(0.322)***	(0.322)***	(0.101)**	(0.101)**	(0.101)**	(0.101)**
Interaction term: (Average share of hydrocarbons in GDP, 1980-1990) * (industry intensity with respect to human capital of ...)								
proxy for low-skilled labor intensity								
	hc^2	hc^3	hc^4	hc^5	hc^2	hc^3	hc^4	hc^5
low skills	1.481	0.7	0.567	0.512	0.789	0.681	0.771	0.912
	(1.599)	(1.093)	(0.996)	(1.05)	(0.924)	(0.709)	(0.711)	(0.78)
high skills	–4.458	–4.374	–4.5	–4.588	–3.23	–3.612	–4.155	–4.749
	(2.663)*	(2.932)	(3.226)	(3.655)	(1.667)*	(1.700)**	(1.840)**	(2.102)**
Industries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417	417	417	417	304	304	304	304
R-squared	0.44	0.44	0.44	0.44	0.56	0.56	0.56	0.56
F-test: $\gamma^{low} = \gamma^{high}$	2.48	1.85	1.6	1.27	3.95	4.5	4.72	4.52
P- value of F-test	0.12	0.17	0.21	0.26	0.05	0.03	0.03	0.03
Robust standard errors in parentheses								
* significant at 10%; ** significant at 5%; *** significant at 1%								

Columns (1) — (4) — equation (1) is estimated on full sample, columns (5) — (8) — only on those observations with positive average growth rates over the period.

Table 7. Industry Growth and Demand for Human Capital of Various Levels, 1990—2000. Measure of resource abundance — Average share of hydrocarbon production to GDP, 1990—2000

Dependent variable: Industry's Real Annual Growth, 1990—2000								
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of industry in total manufacturing value added, 1980	–0.244	–0.246	–0.245	–0.245	–0.36	–0.36	–0.358	–0.355
	(0.121)**	(0.121)**	(0.122)**	(0.122)**	(0.173)**	(0.175)**	(0.176)**	(0.176)**
Interaction term: (Average share of hydrocarbon production to GDP, 1990—2000) * (industry intensity with respect to human capital of ...)								
proxy for low-skilled labor intensity								
	hc^2	hc^3	hc^4	hc^5	hc^2	hc^3	hc^4	hc^5
low skills	6.376	4.856	4.734	5.132	8.557	6.219	5.878	6.193
	(4.811)	(3.39)	(3.104)	(3.169)	(5.383)	(3.821)	(3.568)	(3.714)*
high skills	–20.854	–23.352	–25.929	–28.743	–17.008	–19.048	–21.572	–24.589
	(7.517)***	(8.705)***	(9.917)***	(11.126)**	(6.751)**	(7.448)**	(8.513)**	(9.908)**
Industries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries' fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417	417	417	417	265	265	265	265
R-squared	0.48	0.48	0.48	0.48	0.51	0.51	0.51	0.51
F-test: $\gamma^{low} = \gamma^{high}$	5.22	5.67	5.7	5.73	5.94	6.05	5.84	5.56
P- value of F-test	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02
Robust standard errors in parentheses								
* significant at 10%; ** significant at 5%; *** significant at 1%								

Columns (1)—(4) – equation (1) is estimated on full sample, columns (5)—(8) – only on those observations with positive average growth rates over the period.

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