A New Test of Economy-wide Factor Mobility
Preliminary Draft

Eric O'N. Fisher
efisher@calpoly.edu

Kathryn G. Marshall
kmarsh@ucr.edu

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Abstract

A standard assumption in many models of international trade is that all factors of production are mobile between sectors. This paper constructs a simple Wald test based upon that hypothesis using consistent data from the World Input-Output Database that covers 35 industries and up to 4 factors in 40 countries. The null hypothesis of frictionless factor markets cannot be rejected in 24 countries in the benchmark year 2005 for two factors, labor and capital. We also evaluate a breakdown of skilled and unskilled labor based on college education. In 19 countries we cannot reject the null hypothesis of factor mobility at this more disaggregated level. In those 16 countries in which labor and capital are immobile, we show substantial distortions reflected in excess earnings by either labor or capital, depending on the country.

1 Introduction

A long-standing debate in international trade is the degree to which various factors of production, such as skilled and unskilled labor and capital, are industry-specific or are free to move between sectors. If factors are specific to industries, one would expect to find substantial differences in factor returns across industries. If they are mobile between sectors, one would expect to find similar factor returns across industries. Hence, the degree of factor mobility has huge implications for how the benefits of trade are distributed, and it is the basis for a large theoretical and empirical literature on the political economy of trade. The implication of interindustry factor price equalization extends well beyond debates on the impact of international trade. For instance, it informs Baumol (1967)'s famous cost disease argument that productivity growth in manufacturing will raise wages and hence costs in service sectors.

There is no shortage of theoretical models which examine the implications of differing assumptions about inter-industry factor mobility; what is lacking is an empirical test of factor mobility derived from standard trade theory. The main contribution of this paper is to present such a test based on the simplest implication of neoclassical trade theory: that factor payments reflect goods' prices, conditional on the local technology. We perform a novel Wald test on consistent data from forty countries in 2005. These data record four factors: high skilled labor, medium skilled labor, low skilled labor, and capital. The designations of skills are based on differing levels of education. We find that at the highest level of aggregation–with one type of labor and capital–about two-thirds of our sample countries exhibit economy-wide factor mobility. For all but five of these countries, we are able to confirm mobility that distinguished skilled labor by college education. We find a diverse group of 16 countries that do not exhibit factor mobility in 2005 and we verify that these countries have substantial excess earnings to labor or capital.

Hiscox, a prominent scholar of the political economy of trade, infers the degree of factor mobility by changes in the coefficient of variation of wages and rents over time, but he cautions that factor returns may vary across industries for many reasons even in the presence inter-sectoral mobility. We confirm a high degree of variability of factor payments between industries, but it is in just this sort of environment that a statistical test is appropriate to sort out random variation from economically meaningful payment differentials. Our Wald test also combines payments to both capital and labor based on the local technology of production, which can differ substantially between countries.

In the following section we briefly review the extensive economic and political science literature on the topic of factor mobility. We then present the theoretical foundations of our statistical test in the framework of the famous Lerner diagram. Next we discuss the main features of the extensive World Input-Output Database that allows us to apply our statistical test using detailed industry data for a wide sample of countries. We then present our results followed by a brief conclusion.

2 Review of the literature

The seminal work of Heckscher and Ohlin established the neoclassical foundations of modern trade theory almost one hundred years ago and has spawned a vast literature. A key result of the Heckscher-Ohlin model, the Stolper-Samuelson theorem, shows how goods prices determine factor prices when factors are free to move between industries, thereby equilibrating the return to each factor regardless of sector of employment. To the extent that world trade determines goods prices, the Stolper-Samuelson theorem introduces a strong political motivation for trade policy, since payments to the factor owners, e.g. landowners, workers and capitalists, will be altered by trade with some losers and some winners.

In an important modification of the basic neoclassical trade model, Samuelson (1971) and Jones (1971) note that at least some factors, typically distinct forms of capital, may be immobile between sectors for some period of time, and hence may earn a different rate of return. Labeled by Samuelson as the Ricardo-Viner model, this alternative to the Heckscher-Ohlin framework raises the question of whether in a given country in a given time, factors are mobile or immobile. The textbook answer, that factors are immobile in the short-run and mobile in the long-run, ignores the possibility that coalitions of interest groups can impose industry protections that reinforce factor immobility and amplify its attendant payment differentials. For example, Grossman & Helpman (1994) build a detailed model of endogenous trade policy by assuming that production in each industry combines labor with an industry-specific form of capital, and owners of the specific capital make political contributions to win trade protection for their own industry.

In the political science literature, Rogowski (1990) elaborates the standard Heckscher-Ohlin trade model into a vivid foundation of class conflict based on ownership of factors of production, with illustrations of consequent political battles from over the course of human history. Hiscox (2001, 2002) notes that Rogowski simply assumes that political cleavages fall along class lines, whereas Hiscox devises several indicators of factor mobility to help determine whether trade policy will be shaped by class or industry interest groups. In a sample of six industrial countries over almost two centuries, Hiscox documents a complex picture of factor mobility across countries and over time based primarily on changes in the coefficient of variation of the wage and profit rate across industries. He describes a variety of influences on the degree of factor mobility, including a country's level of economic development, the nature of technological innovation, and the regulatory regime.

Hiscox's detailed studies continue to inspire research on how the degree of factor mobility shapes and is in turn shaped by government policies. Focusing on the US, Ladewig (2006) acknowledges the difficulty of independently measuring factor mobility and uses political outcomes to determine whether factors are mobile or not, concluding that factor mobility in the US has increased over the course of the 1980s and 1990s. Hwang & Lee (2014) consider how labor mobility influences government spending through social welfare or industry subsidies in 31 OECD countries, relying on a measure of job switching between sectors to indicate the degree of mobility. In an international comparison of 77 countries, Pennock (2014) argues that landowners deliberately reduce the educational access of rural workers to limit their options for industrial employment, thereby assuring low wages for agricultural production.

Baumol's 1967 conjecture that high wages in manufacturing will spill over to higher cost in the service sector continues to inform studies of the United States economy, such as Nordhaus (2008) and Autor & Dorn (2013). In a recent popular account of his earlier academic work, Baumol & Ferranti (2012) gives a convincing account of the cost disease that highlights the simple but appealing logic of factor mobility: workers of the same general skill level should expect to earn the same general wage level regardless of the industry of employment. Nevertheless, labor economists such as Dickens & Katz (1987) and Gittleman & Wolff (1993) have long documented distinctive patterns of wage differentials across industries.

These studies collectively document the importance and difficulty of measuring factor mobility. Our unique approach relies on an analysis of production technology that considers the cost of both labor and capital in a given industry. We explicitly recognize that factor payments will vary to some degree across industries, and we sort out the degree of variability with standard statistical procedures in the context of a null hypothesis derived in a straight-forward way from the Stolper-Samuelson theorem.

3 The Theory

3.1 Unit-value technology matrices

The usual starting point for the analysis of a country's technology is the $n \times f$ matrix of direct and indirect unit input requirements:

$$A(w)$$

where w is the $f \times 1$ vector of local factor prices. Its canonical element

$$a_{ij}(w)$$

is the direct and indirect input requirement of factor j per unit of output of sector i. These are physical units, such as hours of unskilled labor per kilograms of apples or real dollars of capital per kilogram of apples.

Under the assumption of constant returns to scale and no joint production, this matrix is a complete description of the supply side of an economy. The matrix $A(w)$, however, is *not observable* because input-output data are recorded as flows of dollars between sectors, and the only natural definition of a unit of good i is actually a dollar's worth of that good. Almost every empiricist who works with these matrices actually observes a point on the *unit-value* isoquant, not the unit-quantity isoquant.

For many practical purposes, this point is moot. It amounts simply to rescaling the rows of the matrix $A(w)$, a point that Leontief (1951) emphasized. Indeed, the unit-value isoquants can be constructed from the physical matrix $A(w)$. Local unit costs are the $n \times 1$ vector

$$p = A(w)w.$$

Write $P = diag(p)$. Then the *observable* unit-value matrix is:

$$V(w) = P^{-1}A(w)$$

The unit value matrix actually contains more information than the physical technology matrix itself. It allows factor prices to be computed from local factor uses, even when goods prices are not observable. Our statistical tests are based upon this remarkable fact. In other words, as long as one defines physical units exactly according to local units costs $p = A(w)w$, then the unit vector is in the column space of $V(w)$. Since $V(w)$ is observable, so is its column space. The consistency of the local input-output matrix can be checked, if one is willing to maintain the ancillary assumption of homogenous factors that are mobile between sectors.

This approach to input-output accounting has an added bonus. For the moment, let us drop the dependence of $V(\cdot)$ on factor prices. If local factor prices are not observable, then they can be calculated using the Moore-Penrose pseudo-inverse of the unit-value matrix:

$$w = V^{+}1_{n\times 1} + (I - V^{+}V)z \tag{1}$$

where $z \in \mathbb{R}^f$ is arbitrary. Equation (1) actually gives the set of all factor prices that are consistent with a given unit-value matrix V. This formula works in all cases, even when there are more factors than goods or the unit value matrix is singular. Still, in almost all empirical applications, the number of sectors n is much larger than the number of factors f. This means that $I - V^+V = 0$, as long as V has full rank f. In this case, factor prices are uniquely defined by (1). When V^TV has full rank, there is a simple equation for the pseudo-inverse:

$$V^+ = (V^TV)^{-1}V^T.$$

The Moore-Penrose pseudo inverse is intimately related to the least squares estimator!

This fact has important applied theoretical implications that are not yet widely appreciated. The relation

$$V(w)w = 1_{n\times 1} \tag{2}$$

actually constitutes an over-determined system of n equations in f local factor prices. This means that the consistency of the unit-value matrix can be checked statistically. One can run a regression of the unit vector on the columns of $V(\cdot)$ to see how closely it fits into that column space. The coefficients from that regression are the best estimates of local factor prices. Since we observe the economy-wide factor prices in the macroeconomic data, we can test whether the estimated coefficients from this regression are equal to the hypothesized values. This simple Wald test is the basis for our statistical analysis.

3.2 Rethinking the Lerner diagram

This subsection will use two diagrams to illustrate the ideas we have just adumbrated. It is based on the notion that a regression of a vector of ones onto factor uses by sector gives the best estimate of local factor prices.

Trade theorists owe a great debt to Lerner (1952), who created the canonical diagram relating factor costs and output prices. Figure 1 depicts this unit-value matrix:

$$V = \begin{bmatrix} 3 & 1 \\ 2 & 2 \\ 1 & 3 \end{bmatrix}.$$

There are $n = 3$ goods, and $f = 2$ factors. The first column shows inputs of labor per dollar of output in each sector, and the second column shows inputs of capital per dollar of output. The actual elements of $V(w)$ are given by the points of tangency, and we have depicted three unit-value isoquants to show that the input mixes minimize unit costs in each industry. We have not included numerical coordinates so that diagram will not be cluttered. Figure 1, the classic Lerner diagram, shows how marginal revenue in a perfectly competitive industry just covers factor costs when firms operate at minimum efficient scale in the long run. It is the fundamental pedagogical tool in discussing the simplest extension of the Heckscher-Ohlin model to the case where there are more goods than factors.

We would like to make two points. First, the factor prices in this diagram are calculated as $w = V^+1_{3\times 1}$. This point was not known to Lerner, and it is not yet widely understood among trade theorists. We first showed how to calculate local factor prices using the Moore-Penrose inverse in a different framework in Fisher & Marshall (2011), but our big advantage now is that

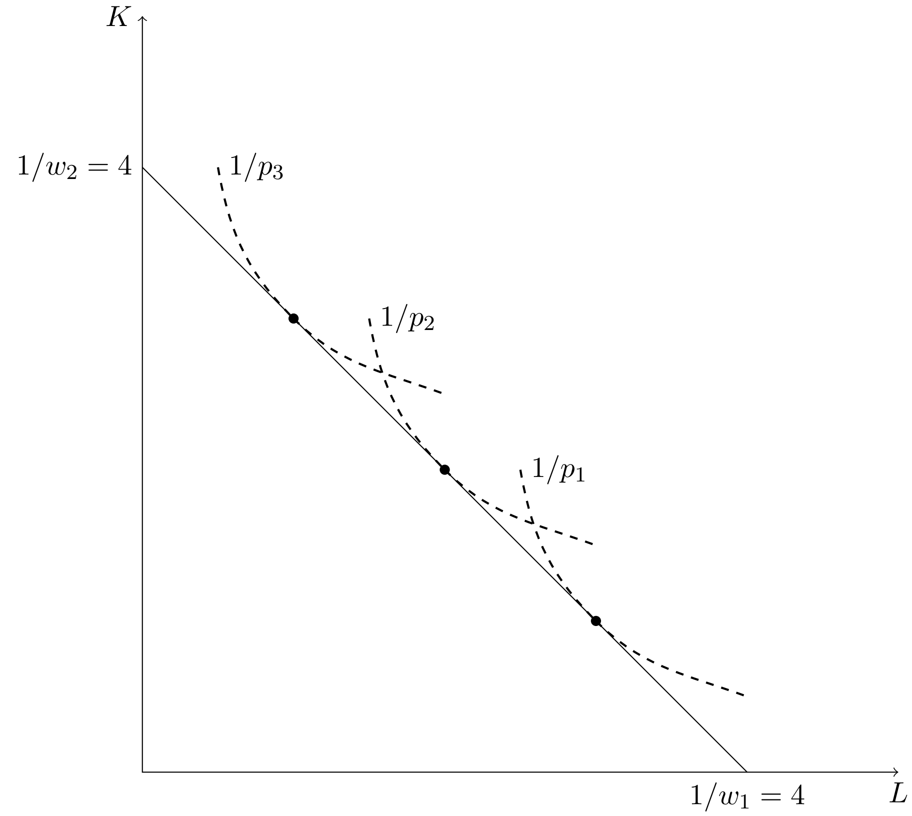


Figure 1: The Lerner diagram with three goods

we are using unit-value matrices, not factor cost shares in every industry. Second, the econometrician can check immediately whether the technology matrix V is measured consistently. All the unit input coefficients must lie in its column space; *in this two-dimensional diagram, they must line up exactly*.

Let us now consider a more realistic and typical case. Figure 2 depicts a slightly different unit-value matrix:

$$V' = \begin{bmatrix} 2.9 & 0.9 \\ 2.2 & 2.2 \\ 0.9 & 2.9 \end{bmatrix}$$

Simple calculation shows that the new factor prices are

$$w' = \begin{bmatrix} 0.249 \\ 0.249 \end{bmatrix} = V'^{+} 1_{3\times 1}.$$

Since the data on factor uses do not lie on the same line, the econometrician must conclude that either unit values or factor uses or both are being measured inconsistently

The cost-minimizing inputs of capital and labor are drawn for each sector for the actual wage-rentals ratio of unity. These input choices emphasize that we are depicting a long-run situation; the tangents to these isoquants (not shown) actually have the same slope as the economy-wide wage-rentals ratio. The unit value isoquants have curvature, and we are not depicting a technology with fixed coefficients for good reason. The representative firm in every sector is minimizing costs by its choices of capital and labor, but the unit values in each sector may be measured with error by the econometrician.

The usual theoretical analysis would explain that the prices of the first and third goods have risen and that of the second good has fallen; given the factor prices shown in the diagram, the second sector is not competitive, and it will shut down. Also the first and third sectors are making pure economic rents, and those sectors will drive up local factor prices or drive down output prices until the economy-wide zero-profit conditions in both remaining sectors are achieved. The general result is this: in an economy with f factors and $n > f$ sectors, it will generally be the case that only f sectors are actually active for an arbitrary specification of output prices p. Our data consist of unit-value matrices with $n = 35$ sectors and at most $f = 4$ factors in each country.

Of course, in the data, almost every sector in every country actually produces positive output. In input-output data, one actually does see sectors that are shut down, where the relevant row of the technology matrix consists of zeros. But this occurs at most in two or three of thirty-five sectors for any country in our data. If the theory were completely correct, then this outcome would be impossible (unless local prices satisfied very many over-identifying restrictions). On the other hand, this situation might occur if the econometrician is measuring the unit-value matrix with error. Perhaps aggregation across firms in each industry introduces measurement error. Perhaps different sectors have slightly different profit margins that are not recorded in unit input costs. It might be the case that factors are not perfectly mobile across sectors, or factors are not actually homogeneous. Indeed, capital or labor may be specific in many different sectors.

This measurement error has nothing to do with the observation of Melitz (2003) that efficient firms tend to export. We are using the simple fact that aggregation schemes in macroeconomic accounts record many more active sectors than factors of production. In fact, since we compute robust standard errors, we are quite agnostic about the sources of measurement error in these technology matrices. But there can be no doubt that average factor use in each sector is measured with error in the data that are typically used in computable general equilibrium models or empirical international trade.

3.3 Our Wald test

In this subsection, we show exactly how we conduct the Wald test for factor mobility and homogeneity. Assume that the observed economy-wide factor prices $w = (0.25, 0.25)^T$ are consistent with those in Figure 1, but the econometrician observes the data on factor use in Figure 2. The predicted unit costs for technology

$$V' = \begin{bmatrix} 2.9 & 0.9 \\ 2.2 & 2.2 \\ 0.9 & 2.9 \end{bmatrix}$$

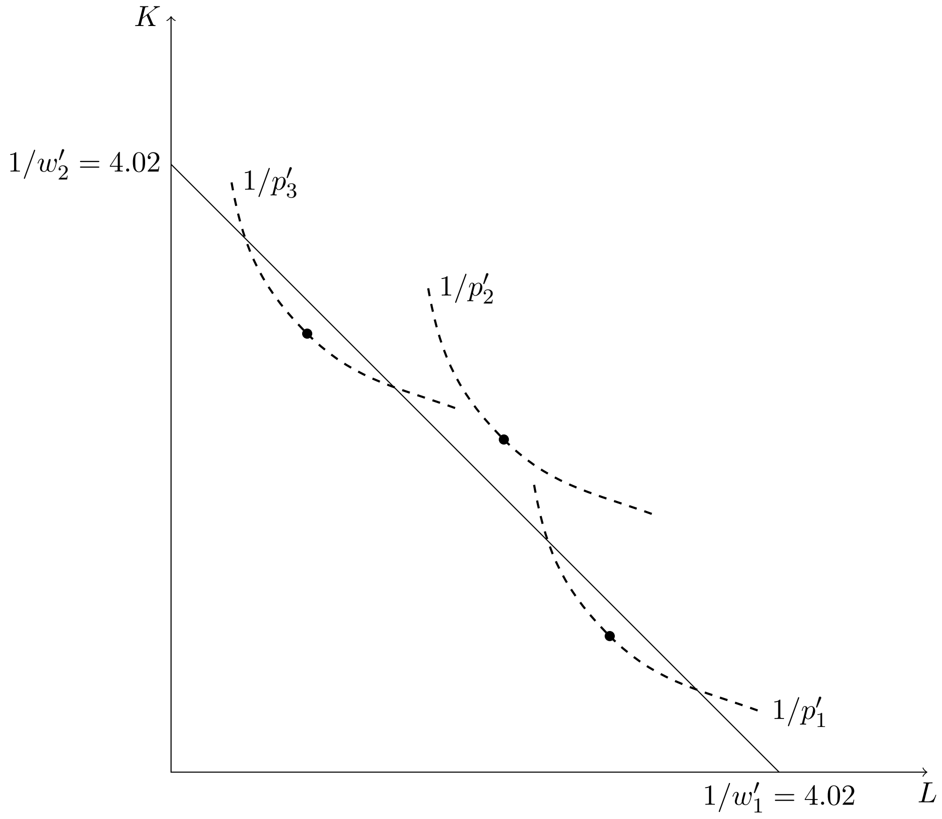


Figure 2: Three unit-value isoquants without a common tangency. Factor prices are the estimated coefficients from a regression of a vector of ones onto factor uses by sector.

are

$$\hat{p} = V'V'^{+}1_{3\times1} = \begin{bmatrix} 0.9453 \\ 1.0945 \\ 0.9453 \end{bmatrix}.$$

The residual sum of squares is:

$$RSS_1 = (\hat{p} - 1_{3\times1})^T(\hat{p} - 1_{3\times1}) = 0.0149$$

The predicted local unit costs under the restriction that $w = (0.25, 0.25)^T$ are:

$$\tilde{p} = V'w = \begin{bmatrix} 0.95 \\ 1.1 \\ 0.95 \end{bmatrix}$$

and the restricted sum of squares is:

$$RSS_2 = (\tilde{p} - 1_{3\times1})^T(\tilde{p} - 1_{3\times1}) = 0.015$$

Since the restricted sum of squares imposes $f = 2$ restrictions and the factor prices are estimated from a regression with $n - f = 3 - 2 = 1$ degree of freedom, the Wald test is constructed from the simple ratio:

$$F(f, n-f) = \frac{(RSS_2 - RSS_1)/f}{RSS_1/(n-f)} = \frac{(0.015 - 0.0149)/2}{0.0149/1} = 0.0034. \quad (3)$$

For a test of any reasonable size, one could not reject the null hypothesis that all factors were mobile, even though by inspection of Figure 2, the econometrician knows that the unit vector does not lie in the column space of V'. In this case, the slight measurement error in V' is of no statistical significance, and the maintained hypothesis of homogeneous factors earning identical returns in every sector is not rejected. Our actual tests use robust standard errors, so there is a slight modification to (3) using the estimated variance-covariance matrix from the regression based on (2).

Our null hypothesis is that factors are homogenous and mobile across sectors. Our alternative hypothesis is that unit value isoquants may be so distant from the isocost line based on the best estimate of common factor payments that random variations and measurement error are implausible explanations. In other words, when we reject the null hypothesis we claim that it is more likely that factors earn distinct payments in different sectors, as would be predicted in a non-mobile world. However, we assess this variability with a carefully constructed statistical hypothesis test and we have combined factors in a given industry in an economically meaningful manner.

4 The data

To implement our Wald test, we need to observe the unit value technology matrix and the economy-wide factor payments in a given country. The recently released World Input-Output Database (WIOD) provides such data for forty countries, representing about seventy-five percent of world GDP.[1] These countries include all the large developed economies and also major developing economies such as China, India, and Indonesia. A novel feature of this database is the combination of consistent input-output tables with extensive social and economic data including three types of labor and physical capital employed in thirty-five sectors.

We convert the input-output data into the unit value technology matrix in the following fashion. First we construct an $n \times f$ matrix of direct factor usages. The units are hours of unskilled labor per year, hours of middle skilled labor, hours of high skilled labor, and real dollars of capital. The skill category refers to levels of education where high skilled is tertiary or college education, medium school is secondary or high school education, and low skill is primary or elementary school education. We consider several aggregations of these skill categories, described in greater detail later. Factor usage is recorded for 35 sectors encompassing 14 distinct manufacturing sectors and a wide range of other goods and services sectors.

Intermediate goods flows between sectors are recorded in an $n \times n$ matrix whose typical element is dollars per year.[2] Reading down a column, one sees dollars of different goods purchased

[1] See Timmer (2012) for complete details.

[2] Conversions from local currency to US dollars are made with market exchange rates.

by an industry for its intermediate inputs. Reading across a row, one sees dollars of different goods sold to an industry. The row sums and column sums of these matrices must be equal, and an important part of national accounts is balancing these tables. The commodity flows are values; it is impossible to distinguish quantities from prices without further assumptions about the data.

One must divide the elements of the commodity flow matrix by its column sums. This normalization entails that one has now defined intermediate inputs per dollar of input in a sector. In particular, the commodity flow matrix now has no units. *Its elements are scalars*. The logic of Leontief's algebra then allows one to calculate easily the infinite recursion of all the rounds of intermediate goods usages, and one inverts a simple matrix. Each element of this inverted matrix again is a scalar.

Now comes the key step in defining a unit-value matrix. The direct factor uses are recorded in physical units of a factor per year. The input-output table's column sums are dollars of output per year. In constructing the Leontief matrix, one normalizes by these column sums. *The same normalization must be applied to direct factor uses.* For example, one divides hours of low skilled labor per year by dollars of output per year, and the resulting units are hours of low skilled labor per dollar of output. This is a unit value. There is a nice subtlety; since direct capital input is measured in real dollars per year, its unit value is a scalar and should be properly interpreted as a gross rate of return.

The final step is to multiply the $n \times n$ Leontief matrix by the $n \times f$ matrix of unit values. This is how one constructs a consistent matrix $V(w)$. One other minor comment is in order. Since one multiplies on the left by the square Leontief matrix, $V(w)$ is linear in the columns of the direct factor use matrix. That means that it is completely consistent to aggregate hours of low skilled labor per dollar of apple output with hours of middle skilled labor per dollar of apple output. In brief, our aggregation of labor into one broad category is economically sound.

We also construct the economy-wide payments for each factor in each country by dividing the total value-added payments to that factor, reported in the WIOD, by the total factor usage of that factor. Figure 3 shows these observable factor payments in our sample countries, mapped against GDP per hour worked, also derived from WIOD values. Figure 3 shows the most aggregated verion of labor inputs, but we can easily disaggregate these labor payments into wages by three educational categories.

We can also observe the variation of factor payments across 35 different sectors in each of the 40 countries. We depict this variation for several large economies in Figures 4 and 5. Figure 4 compares Germany to Spain, showing that in both countries there is noticeable variation in factor payments. For example in both Germany and Spain, workers earn more than twice the average wage in the petroleum refining sector and less than half the average wage in the agriculture sector. In both countries the return to capital is more variable across sectors than the average wage. While the degree of variation by sector is again similar, Spain has an unusually high return to capital in financial intermediation, reaching almost 4 times the average of all sectors. Figure 5 depicts and compares the same variation in two large developing nations, China and India.

We present these detailed depictions of factor payments across sectors in these four countries to highlight the level of detail the WIOD provides and the types of industries we observe. To summarize all 40 countries more succinctly, Figure 6 presents the coefficient of variation of the average wage and return to capital. The coefficient of variation has been a standard measure of the degree of factor mobility in the literature, yet our wealth of data brings into focus the challenge of using this single summary statistic to determine factor mobility. Looking at Figure 6, there are certainly some countries with a higher coefficient of variation, but where would one draw the line to separate countries with mobile factors (low coefficient of variation) from those with immobile factors (high coefficient of variation)? Likewise, how should one treat the two distinct factors of capital and labor, when clearly capital has a higher coefficient of variation across all countries? Rather than make arbitrary cut-offs for each factor, our approach brings the production economics of the Lerner diagram together with a straight-forward statistical test of significance, allowing us to apply a uniform analysis to this diverse group of countries.

5 The results

Our Wald test is based on a comparison of the observable factor payments to the predicted payments from the estimated coefficients in a regression of a vector of ones onto factor uses by sector as recorded in the technology matrix V. Our first test focuses on two factors, capital and labor, for the year 2005. We show that for 24 of 40 countries, the null hypothesis of factor mobility cannot be rejected. We then discuss the wage premium for college-educated workers and consider how more refined measures of labor perform in our mobility tests. Finally, we compare the economic features of the countries whose factors are immobile to those countries whose factors are mobile.

5.1 Two factor mobility

Figure 7 depicts the results of our first test with aggregated labor and capital. Since our sample countries have very different payment magnitudes, we present the ratio of the observed average wage and the ratio of the observed rental rate to our estimated wage and rental rate. We are able to accept the null hypothesis of factor mobility for 24 countries.[3] As indicated in the figure, countries for which the null hypothesis is rejected fall roughly equally into two camps: those whose observed wage is above our estimates and those whose observed rental rate is above our estimate.[4]

We present the standard statistical results of each of the 40 regressions in the data appendix. Almost all of the coefficients are statistically significant and greater than zero. Even for those countries for which we reject the null hypothesis of factor mobility, the coefficients of these regressions offer a useful proxy for the economy-wide opportunity cost of labor and capital, a facet of our analysis that we explore later.

Many of the important issues relating to trade and factor mobility hinge on more refined measures of skilled and unskilled labor. For example, do cheap clothing imports reduce the

[3]The countries with two mobile factors are Australia, Austria, Brazil, Canada, China, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Japan, Korea, Lithuania, Netherlands, Poland, Portugal, Romania, Russia, Slovenia, Sweden,Turkey, and the USA.

[4]The countries with immobile factors are Belgium, Bulgaria,the Czech Republic, India, Indonesia, Ireland, Italy, Latvia, Malta, Mexico, The Slovak Republic, Spain, Taiwan, and the United Kingdom.

wages of all unskilled workers or only those in the clothing industry? The considerable challenge to this line of inquiry lies in accurately measuring labor skills across industries and, for international comparisons, across countries. Before considering disaggregated labor tests, we would like to emphasize that our two factor test is not invalidated by unobserved differences in labor quality. Even if we cannot separate different skill types, we are basing our estimated wage on the sum of labor inputs of all skill types captured in the respective column of the technology matrix V. By way of contrast, it is easy to demonstrate that the coefficient of variation of average wages across sectors will increase if the unobserved skill premium increases, even if the more skilled workers earn the same wage in different industries. Likewise, in our test the technology matrix incorporates the inputs of both labor and capital so that we can combine both factors in an economically meaningful way. Figure 7 highlights this distinctive feature by showing the two factors on the same axes.

5.2 Disaggregating worker skill levels

We now evaluate factor mobility for disaggregated skill categories based on educational attainment. We begin by describing the salient features of the WIOD educational data. The WIOD reports worker hours by three levels of educational attainment: high (college-degree or above), medium (high school and vocational school), and low (elementary school and some high school). Of the three educational categories, the share of college-educated hours, shown in Panel (a) of Figure 8, is the most strongly correlated with GDP per worker. The share of medium and low education varies idiosyncratically among countries at similar income levels. For example, Mexico and Turkey have a similar level of GDP per worker and both have about 12 percent of college educated workers. However, Mexico has 40 percent medium educated workers while Turkey has only 20 percent.

Panel (b) of Figure 8 shows that the college wage premium is decisively higher in low income countries. Among very low income countries such as Indonesian and India, college educated workers earn four to five times as much as those with no college. Even in the countries with the lowest premium, Denmark and Sweden, college educated workers earn about 30 percent more than non-college educated workers.

Our analysis of factor mobility among different educational levels depends on detailed industry level statistics of these educational categories. The statisticians who compile the WIOD socio-economic accounts apply Herculean efforts to obtain a disaggregated picture of wages and educational level by industry from a range of national sources, as detailed in Erumban et al. (2012). Even for those European countries included in the extensive EU-KLEMS database, a great deal of extrapolation is involved. For example, the EU-KLEMS data report education and wage breakdowns for at most 14 sectors, so that further disaggregation to 35 industries simply assumes the same portions and relative wages in the corresponding sub-sectors. For seven countries, data on the educational composition by industry simply does not exist, so the statisticians instead apply the educational distribution from another country.[5]

An additional complication is whether the educational level is an accurate indicator for skill-

[5]These seven countries are Bulgaria, Estonia, Lithuania, Latvia, Malta, and Roumania, for which the educational breakdown of Portugal is applied, and Russia, for which the educational breakdown of the Czech Republic is applied.

based wage premia. Among labor economists focusing on the United States economy, the degree of correspondence between educational level and the particular skills or occupations which distinguish high earners from low earners has been subjected to detailed scrutiny. Kambourov & Manovskii (2009) finds that occupational category is a more accurate determinant of wages than either education or industry. This assumption is echoed by Autor & Dorn (2013) who correlate over 300 occupational categories to a smaller set of skills including abstract, manual and routine, skills. Among many of the developing countries in our sample, Pritchett (2013) raises a very different consideration. He documents extensively how the quality of education in many developing countries is so poor that it may not even lead to literacy, let alone marketable job skills.

With these caveats in mind, we first apply our Wald test to the most disaggregated measure of labor together with capital. At this detailed level of disaggregation, we can accept the null hypothesis for 13 countries, all but two of which also show factor mobility when measured by aggregate labor. While these results seem reasonable, the coefficient estimates of the individual types of labor are widely dispersed and often negative. However, if we combine low and medium levels of education and conduct the test for 3 factors including capital, our coefficients are generally well-behaved and we can accept the null hypothesis for 19 countries, all of which also show factor mobility with aggregate labor. We present the results of the 3 factor test in Figure 9.

The 5 countries which show mobility for aggregate labor and capital but not for either version of disaggregated labor are Brazil, Japan, Portugal, Russia, and the United States. There are at least two contributing factors to this outcome: the relatively poor quality of educational data by industry, especially for Russia to which a proxy country was applied, and the poor correlation of labor skills with educational level. Of course the United States is of particular interest as the world's largest industrial economy. Since the United States is also one of the most accurately measured economies in the world, we hope that our method can form the foundation for a more detailed case study using different breakdowns of skills such those described in Autor & Dorn (2013).

5.3 Countries whose factors are immobile in 2005

We have identified 16 countries for which factors are immobile in 2005. For all of these countries, we can reject the null hypothesis of factor mobility at both the 2 factor (labor and capital) and 3 factor level (college educated, non-college educated labor and capital). In the 2 factor case, our regression analysis provides an estimate of the average wage ($\hat{w}$) and return to capital ($\hat{r}$) that comes closest to equating unit costs of production in each sector to the unit price (assumed to be one dollar in all sectors). We can interpret these estimates as proxies for the economy-wide opportunity cost of labor and capital. This interpretation allows us to assess the magnitude of the distortions resulting from factor immobility.[6]

Let T_L represent the observed total payments to labor in a given country, and T_K represent the observed total payments to capital, and let K represent the total stock of capital and L the

[6]Since the sources of factor immobility are many, lumping together sector-specific human capital with regulatory barriers to entry, we recognize that at least some of this measure may reflect healthy market forces.

total hours of labor employed. Our measure of the excess (deficit) payment to labor is given by $T_L - \hat{w}L$ and the excess (deficit) payment to capital is given by $T_K - \hat{r}K$. To compare the magnitudes among different countries, we normalize each excess factor payment by the total payment to that factor.

Figure 10 shows the results of this analysis for the 14 countries with immobile factors, compared to the 26 countries with mobile factors. The size of the distortion is substantial, representing on order of 50 percent of factor payments for countries with immobile factors. Although the number of countries is relatively small, there is considerable diversity in the sense that nine of the countries have large excess payments to capital while seven have large excess payments to labor.

6 Conclusion

Economists and political scientists alike have long been engaged in a debate about who benefits and who looses from international trade. This debate often hinges on whether factors are mobile between industries, but what has been lacking is a statistically well-grounded measure of factor mobility. We recognize that the solution we present in this paper demands a substantial amount of information on the technology of production in each country to which it is applied, but we show that such information is necessary to discern whether or not the normal variability in factor payments across industries obscures an equilibrium consistent with factor mobility. We show that in a slim majority of countries, 24 out of 40, factors are mobile across sectors when we combine all educational levels of labor. In these countries, the evidence substantiates the standard Heckscher-Ohlin results that trade has differential impacts on factor owners. Because our data encompass a detailed 35 industry structure over the entire economy, these results also substantiate broader claims about labor market outcomes, such as Baumol's well-known cost-disease argument.

In 16 countries our two factor test confirms that factors are immobile. The aggregate effects of this immobility are substantial, typically representing around 50 percent of total factor payments. This finding in turn justifies the interest of political scientists in the type of political coalitions that might contribute to industry-specific protections. While we do not explore the political dimensions of the economic outcomes we observe, we hope that our empirical test results will contribute to a better understanding of factor mobility and its implications for trade policy in both the economic and political realms.

Our approach is readily applicable to more refined measures of factor inputs by sector, and the results of our test with skilled labor measured by college education is broadly consistent with our two factor tests. Of the 24 countries with two factor mobility, we confirm that 19 countries exhibit factor mobility for skilled (college-educated) and unskilled labor and capital. However, we cannot confirm this finding for five countries including the U.S. and Russia. While this paper has focused on a large international comparison in one year, our framework is readily applicable to more detailed case studies that can explore different measures of labor skills and evaluate changes in mobility over time.

Table A1: Sectors

No.	ISIC Rev. 3	Description
1	A,B	Agriculture, hunting, forestry and fishing
2	C	Mining and quarrying
3	15,16	Food, beverages, and tobacco
4	17,18	Textiles, textile products, leather and footwear
5	19	Leather and footwear
6	20	Wood and products of wood and cork
7	21,22	Pulp, paper, paper products, printing and publishing
8	23	Coke, refined petroleum products and nuclear fuel
9	24	Chemicals and chemical products
10	25	Rubber & plastics
11	26	Other non-metallic mineral products
12	27,28	Basic metals and fabricated metal
13	29	Machinery, Nec
14	30-33	Electrical and optical equipment
15	34,35	Transport equipment
16	36,37	Manufacturing, Nec; Recycling
17	E	Electricity, gas, and water supply
18	F	Construction
19	50	Sale, maintenance and repair of motor vehicles; Retail sale of fuel
20	51	Wholesale trade
21	52	Retail trade
22	H	Hotels and restaurants
23	60	Inland transport
24	61	Water transport
25	62	Air transport
26	63	Other transport activities
27	64	Post and telecommunications
28	J	Financial intermediation
29	70	Real estate activities
30	71-74	Renting of machinery & equipment and other business activities
31	L	Public administration and defense
32	M	Education
33	N	Health and social work
34	O	Other community, social and personal services
35	P	Private households with employed persons

Table A2: Countries

Name	Abbreviation	GDP per hour worked
Australia	AUS	$39.04
Austria	AUT	$43.66
Belgium	BEL	$59.23
Brazil	BRA	$4.30
Bulgaria	BGR	$4.31
Canada	CAN	$38.48
China	CHN	$1.55
Cyprus	CYP	$22.97
Czech Republic	CZE	$12.35
Denmark	DNK	$47.71
Estonia	EST	$10.94
Finland	FIN	$44.93
France	FRA	$54.73
Germany	DEU	$54.92
Greece	GRC	$23.85
Hungary	HUN	$12.41
India	IND	$1.91
Indonesia	IDN	$0.75
Ireland	IRL	$51.63
Italy	ITA	$38.12
Japan	JPN	$39.23
Korea	KOR	$15.07
Latvia	LVA	$9.54
Lithuania	LTU	$8.93
Luxembourg	LUX	$70.93
Malta	MLT	$19.23
Mexico	MEX	$8.72
Netherlands	NLD	$53.05
Poland	POL	$11.19
Portugal	PRT	$18.48
Romania	ROU	$5.45
Russia	RUS	$4.69
Slovak Republic	SVK	$12.63
Slovenia	SVN	$20.23
Spain	ESP	$33.48
Sweden	SWE	$50.14
Turkey	TUR	$10.71
United Kingdom	GBR	$45.44
United States	USA	$47.42

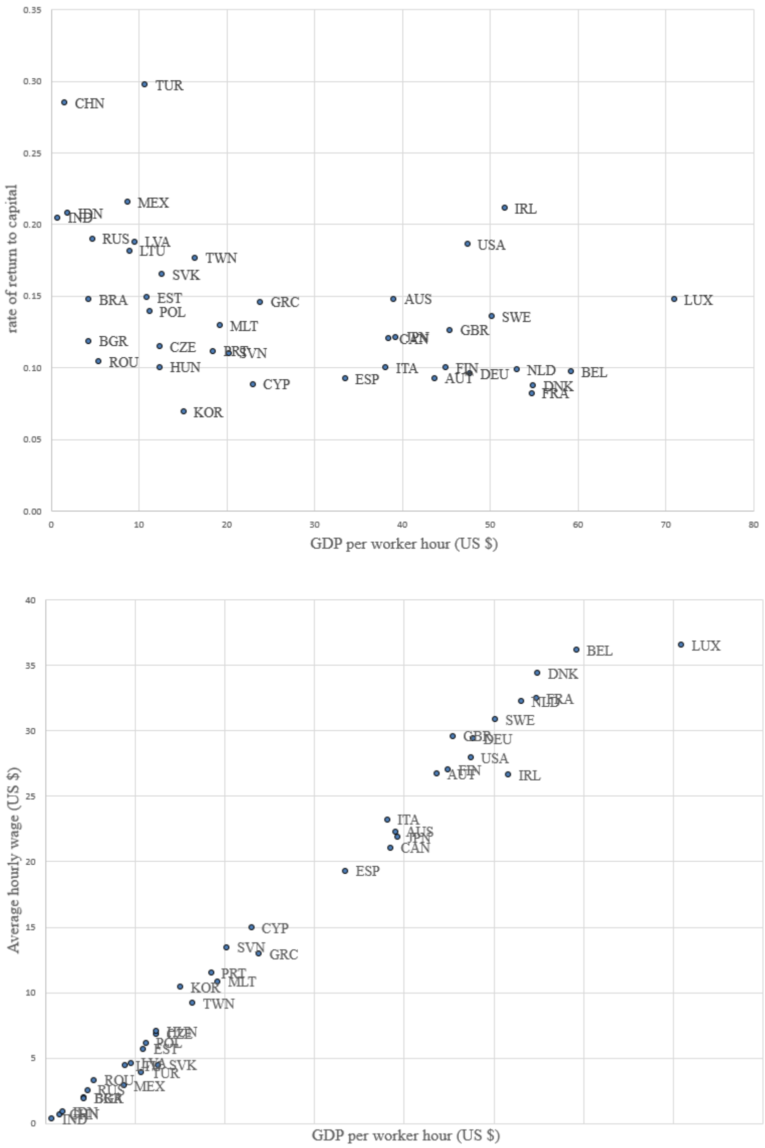
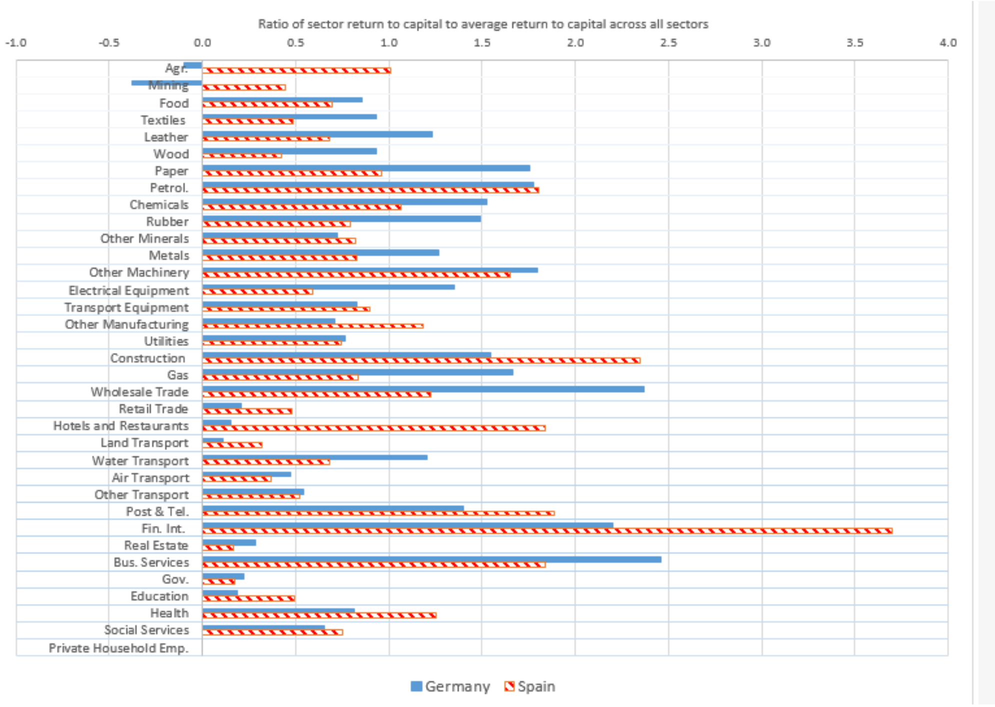
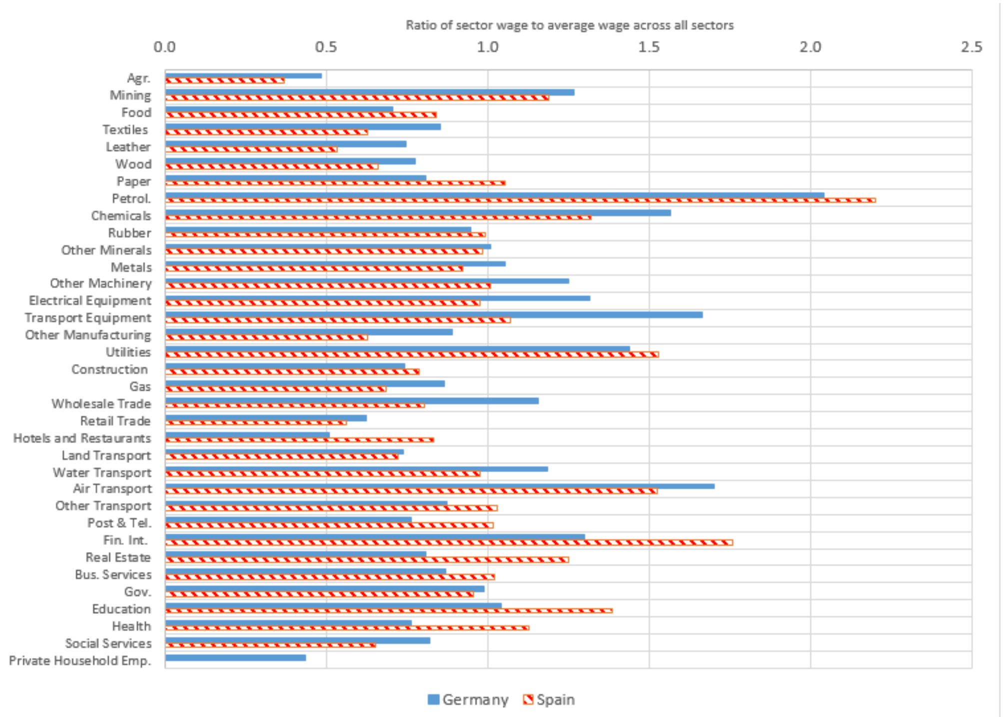


Figure 3: Observable rate of return to capital and average hourly wage in 2005 for forty countries

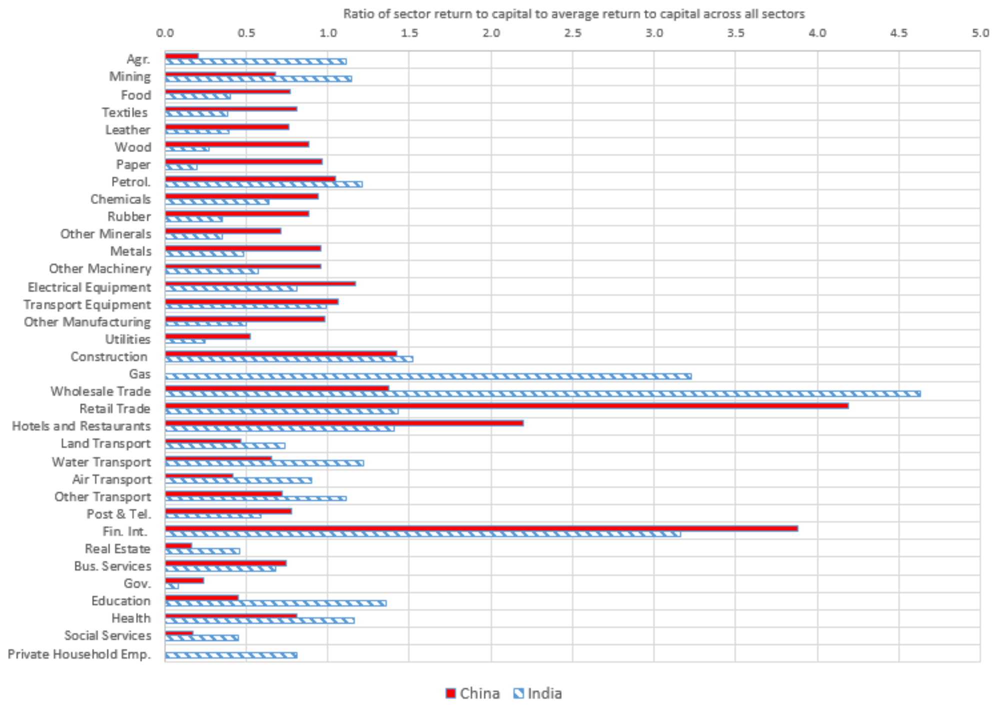


(a) Return to capital

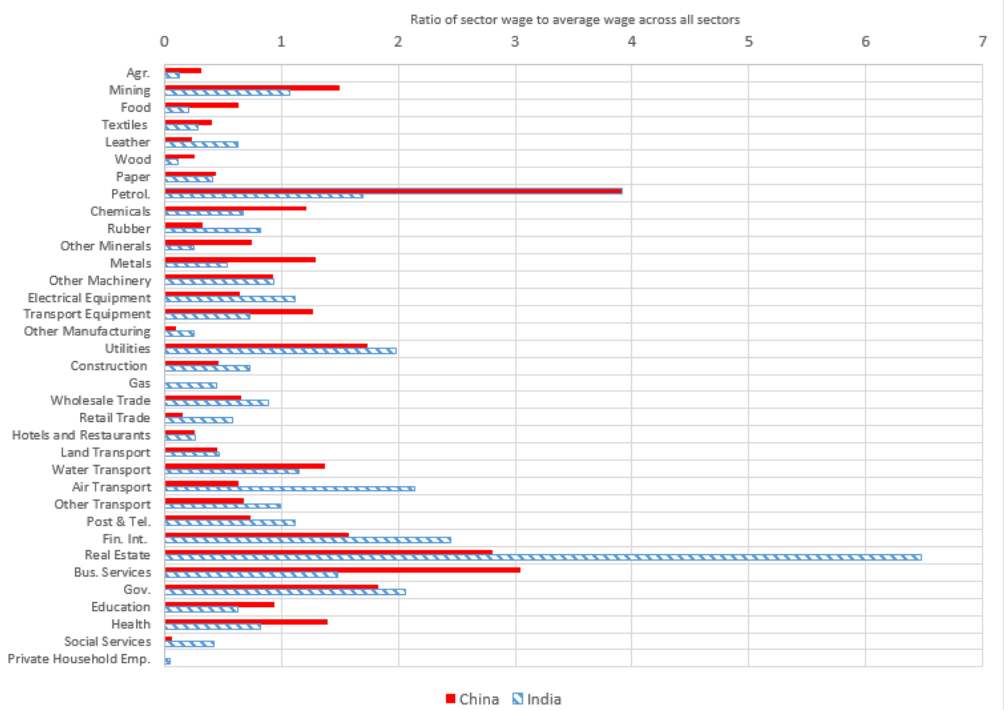


(b) Average wage

Figure 4: A comparison of factor payments across sectors in Germany and Spain in 2005



(a) Return to capital



(b) Average wage

Figure 5: A comparison of factor payments across sectors in China and India in 2005

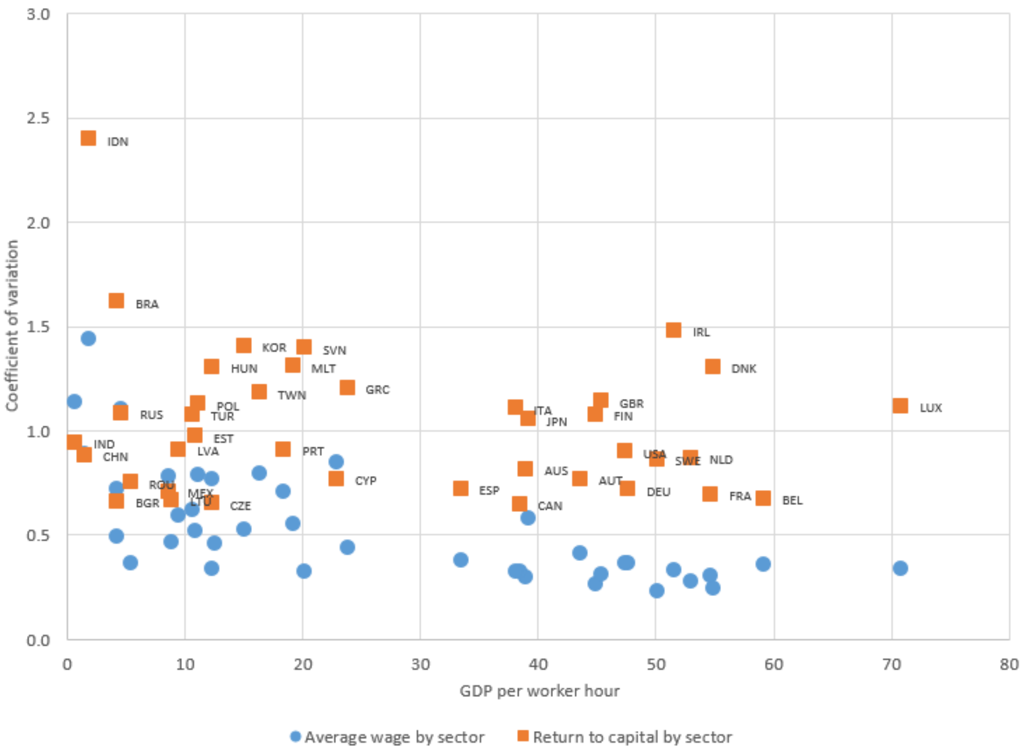


Figure 6: The coefficient of variation in wages and return to capital in 2005 for 40 countries

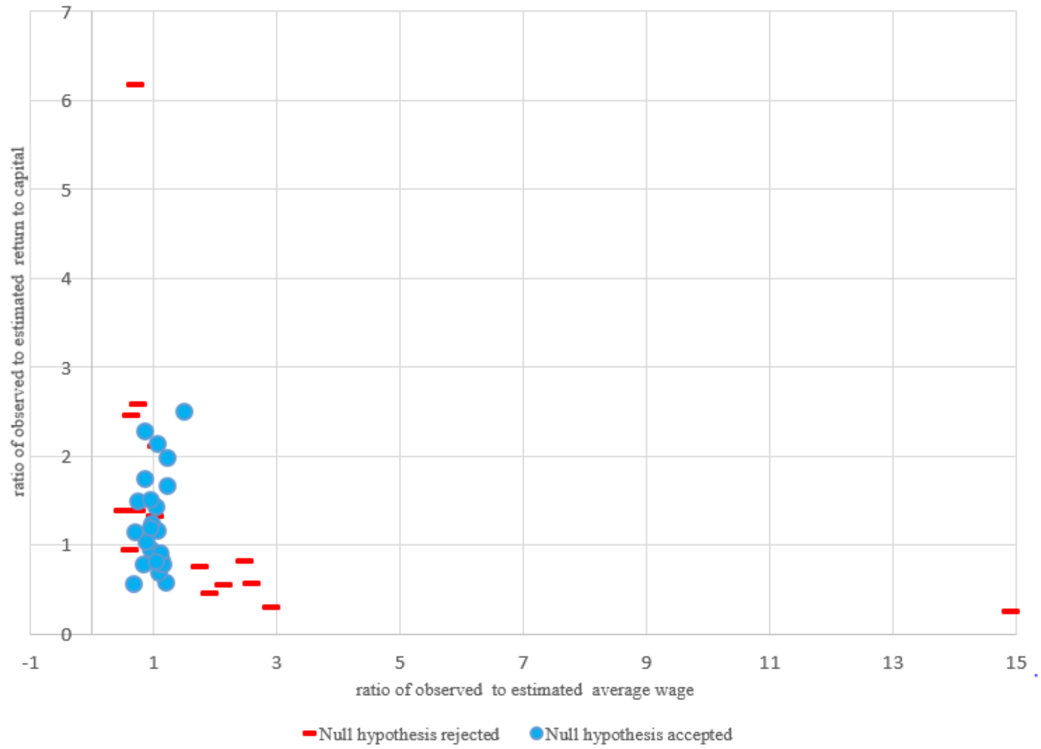
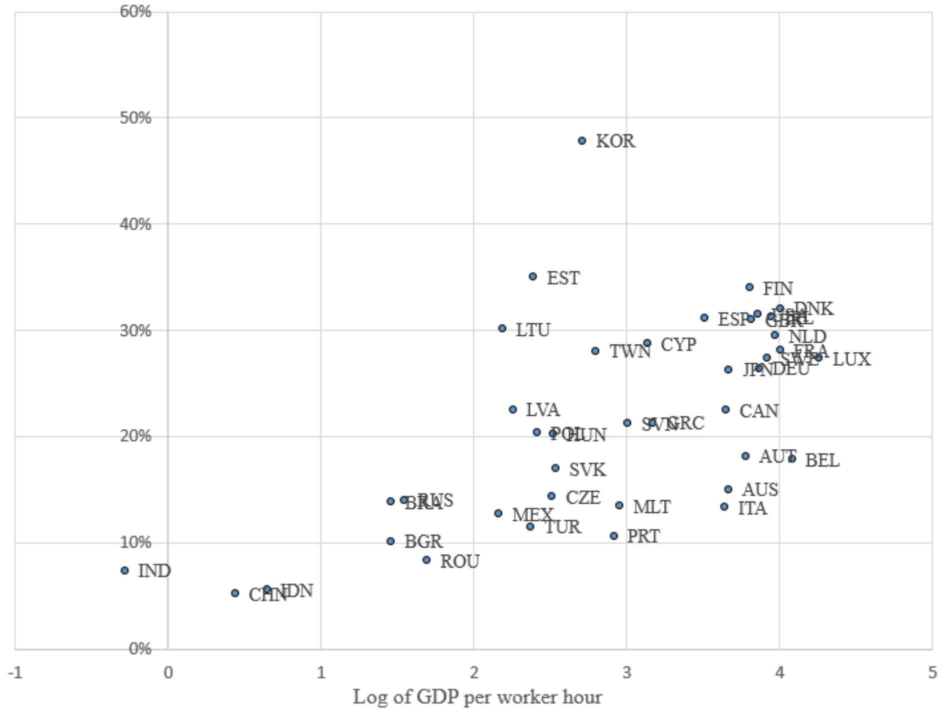
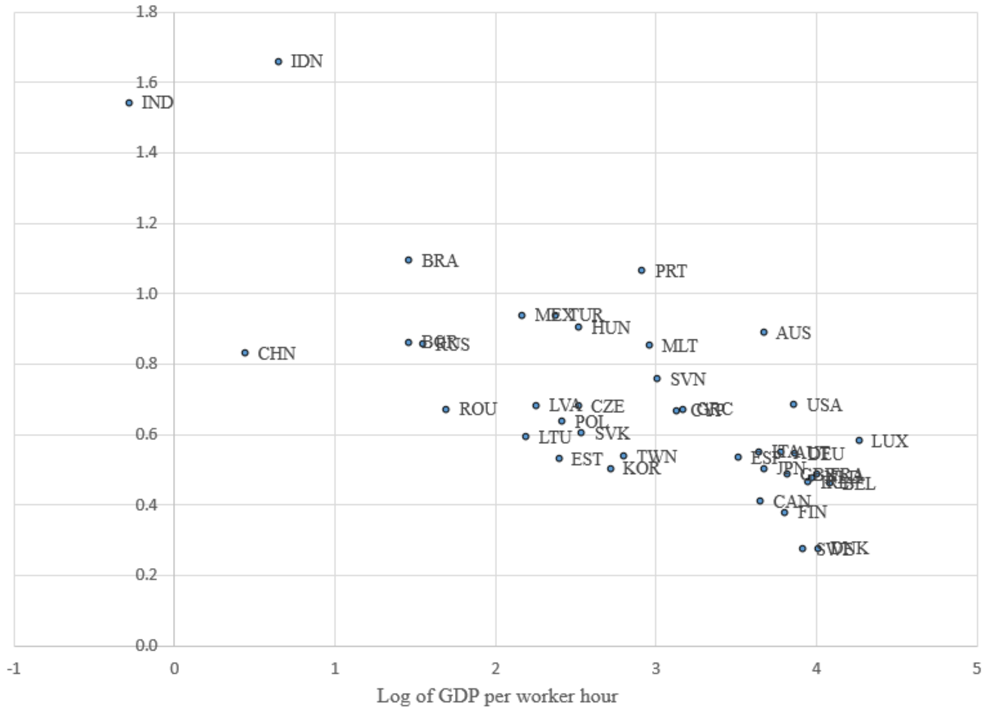


Figure 7: Wald test of null hypothesis of factor mobility for two factors



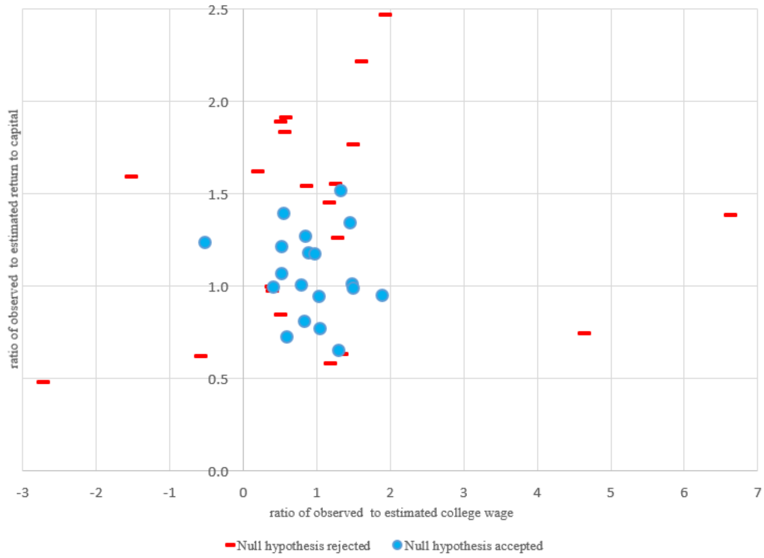
(a) College-educated worker hours, percent of total



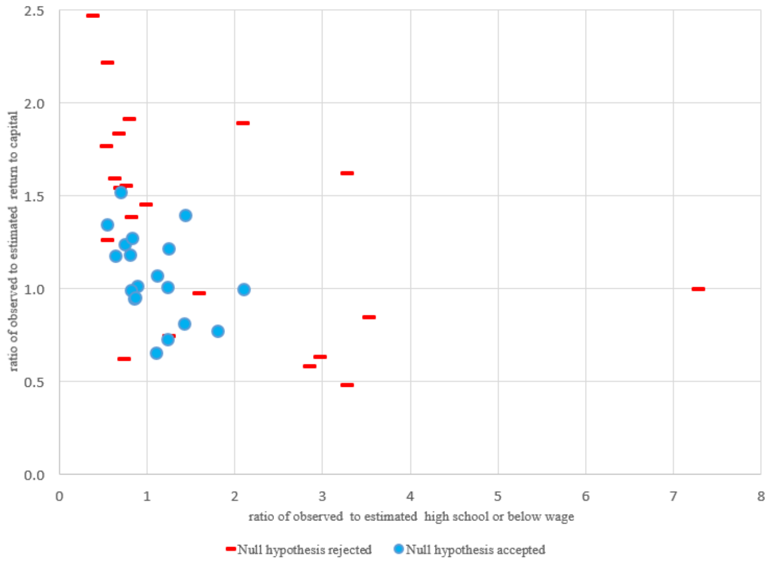
(b) College wage premium

Figure 8: Share and earnings of college-educated workers in 2005

Note: College wage premium is the log of the ratio of the average hourly wage of college-educated workers to non-college educated workers.



(a) College wage and return to capital



(b) High school and below wage and return to capital

Figure 9: Wald test of null hypothesis of factor mobility for three factors

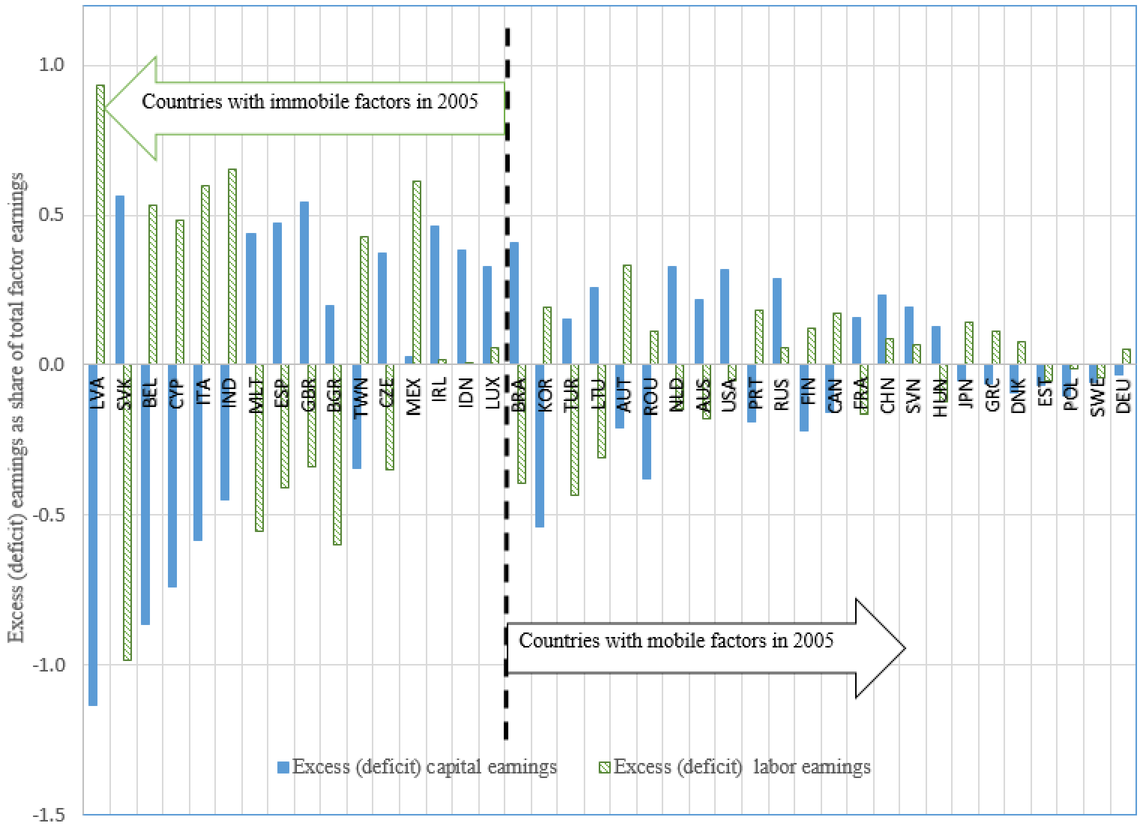


Figure 10: A comparison of select countries whose factors are mobile to those whose factors are immobile in 2005

Note: The "immobility ratio" compares direct inputs (capital and labor) at sector-specific factor payments to the hypothetical unit costs if factors had earned the observed economy-wide payments.

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