A New Test of Economy-wide Factor Mobility
Preliminary Draft

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Abstract

A standard assumption in many models international trade is that all factors of production are mobile between sectors. This paper constructs a simple Wald test based upon that hypothesis. It uses consistent data from the World Input-Output Database that covers 35 industries and 4 factors in 40 countries. The null hypothesis of frictionless factor markets cannot be rejected in 26 countries in the benchmark year 2005.

We evaluate several compositions of labor based on three educational levels. The most appropriate measure of labor skills depends to some degree on the country, but typically distinguishes the college educated worker as high skilled, earning a premium over less educated workers regardless of industry. In those 14 countries where we reject the null hypothesis, we substantiate that diverse industries have abnormally high or low factor costs. We also find that over a ten year horizon, most countries do not move from a state of mobility to immobility or vice-versa, and we show a widely-used alternative measure of factor mobility, the coefficient of variation of factor payments, does not accurately reflect factor mobility when judged by our own test.

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 interindustry 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 over a span of 10 years. 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 four of these countries, we are able to confirm mobility in some subset of labor skills measured by various combinations of educational attainment. We find a diverse group of fourteen countries that do not exhibit factor mobility in 2005 and we verify that these countries have specific industries with unusually high or low factor costs.

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. Although our test does not depend on observations over time, we confirm that there are relatively few instances of transition from mobile to immobile factors or vice-versa over the ten year horizon our data cover.

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 use to apply our statistical test using detailed industry data for a wide sample of countries. We then present our results and a comparison of our results to the alternative measure, the coefficient of variation of factor payments, and 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 in 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 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

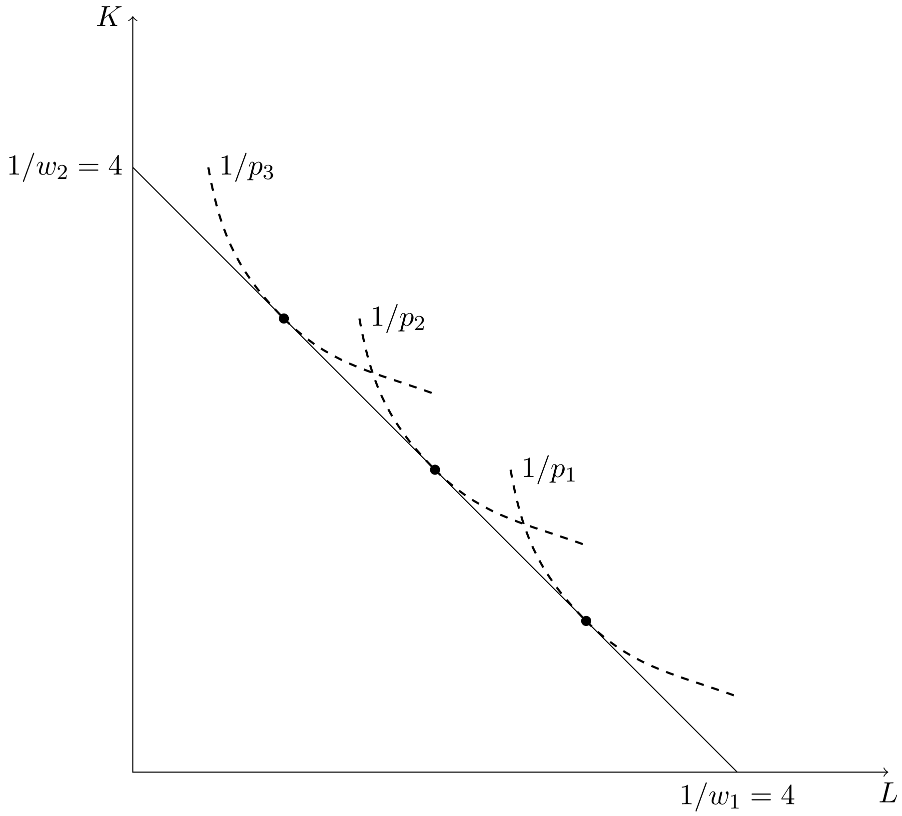

Figure 1: The Lerner diagram with three goods

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 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 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

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

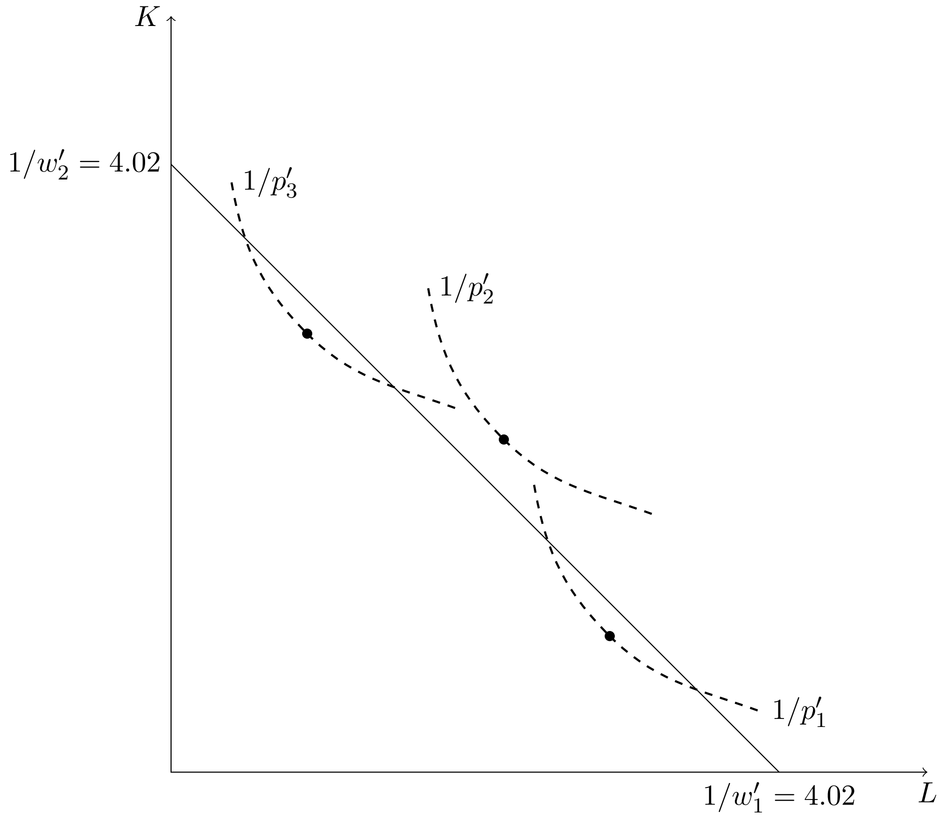

Figure 2: Three unit-value isoquants without a common tangency. Factor prices are the estimated coefficients from a regression of a vector of ones onto factor uses by sector.

are

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

The residual sum of squares is:

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

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:

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

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:

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

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 schoole education, and low skill is primary or elementary school education. 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 toal 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 disaggregated verion of labor inputs, but we can easily aggregate these labor payments into various combinations.

5 The results

Our Wald test is based on a comparison of the observable factor payments, depicted in Figure 3 for capital and three educational levels of labor, 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. We show that for 26 countries in the year 2005, the hypothesis of factor mobility cannot be rejected at some level of labor aggregation. We then consider how more disaggregated measures of labor perform. An important consideration is how well our observed educational categories reflect worker skill levels, especially in a group of countries as diverse as our sample. We begin this section with a discussion of the results of our test for aggregate labor and capital. We argue that our test also sheds light on the appropriate level of labor aggregation,

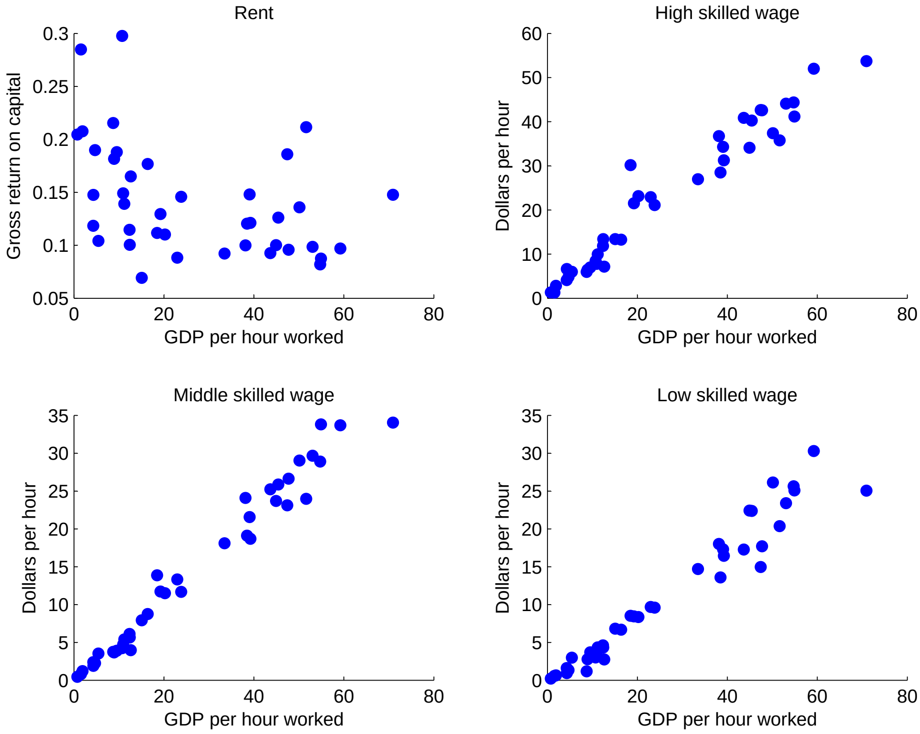

Figure 3: Observable factor prices in 2005 for forty countries

and we examine in detail the results for four different combinations of educational level. Next, we look at the features of those 14 countries which do not exhibit factor mobility in 2005. Finally, we compare our measure to the most widely used alternative measure of factor mobility, the coefficient of variation.

5.1 Two factor mobility

Figure 4 depicts the results of our first two factor test. Since our sample countries have very different payment magnitudes, we present the ratio of the observed average wage for all education levels 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. For only two countries, Luxembourg and Cyprus, do we reject the null hypothesis at this level of aggregation and accept it at a more detailed level of three types of labor. Hence our

[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, Slovenia, Sweden,Turkey, Russia, and the USA.

final set of countries with immobile factors is equal to 14.[4]

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 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 4 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. Here we confront several new complications. First, the industry data distinguishing educational levels is not as accurate as other industry-based measures in the WIOD. Second, the correspondence between education level and skill level is problematic and may vary across countries with very different educational traditions and levels of economic development.

The WIOD reports three levels of educational attainment which can be loosely described as college (high), high school and vocational school (medium), and elementary school (low). 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.

The second complication is how meaningful the educational level is for measuring skill-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

[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.

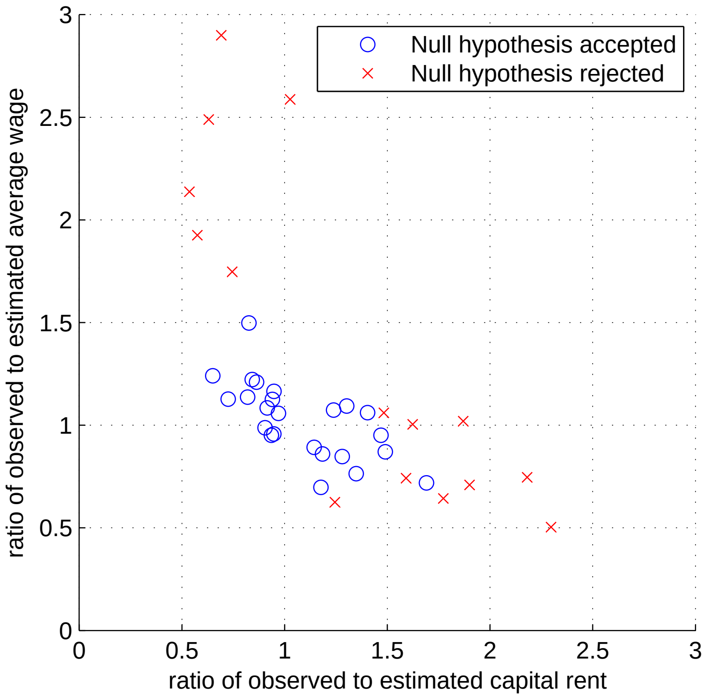

Figure 4: Wald test of null hypothesis of factor mobility for two factors and thirty-nine countries

Note: Latvia omitted since its ratio of observed to estimated wage is, 4.63/0.3, is an outlier.

developing countries is so poor that it may not even lead to literacy, let alone marketable job skills.

To address these varied concerns, we rely on the simple economic logic of our statistical test: under the null hypothesis, the marketplace will reward the same skill-level the same wage regardless of industry. Within the limitations of the data, we can consider several different aggregations of education to obtain alternative measures of the same skill level. The most disaggregated measure is simply based on three skill groups: high, medium and low education. We also consider two ways of forming two skill groups: medium and low educational attainment combined or high and medium educational attainment combined. We perform the Wald test on each of these three combinations, and report the aggregation which performed best in the sense of having the most accurate wage prediction as measured by the probability of the Wald statistic.

For six of our sample countries, Estonia, Korea, Australia, Hungary, Luxembourg, and Cyprus, the most disaggregated test performed the best. Figure 5 demonstrates the remarkable accuracy of our wage estimates for all three educational levels together with the rent paid to capital. For twelve countries, the aggregation of low and medium education performed better than the more disaggregated test. For these 18 countries, a college degree does indeed confer a wage premium regardless of industry of employment. Figure 6 depicts the predicted and observed payments for the three factors, showing that the range of wage levels, from a low in Romania to a high in France, is great. Figure 6 also includes four countries, China, Canada, Japan, and Lithuania, for which the preferred aggregation was high and medium educational level.

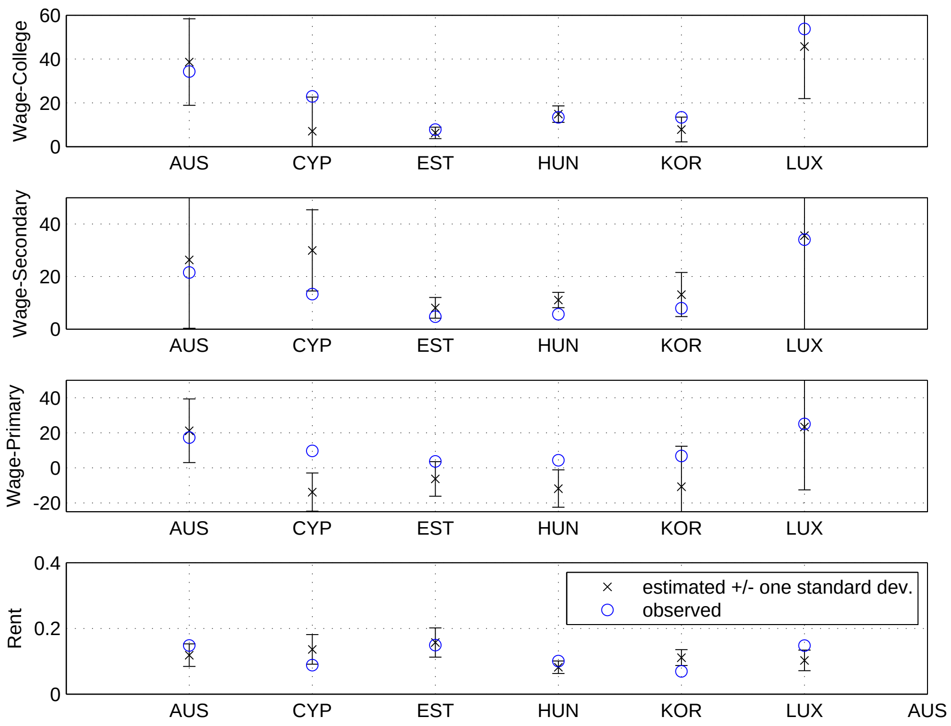

Figure 5: Six countries with four mobile factors in 2005: three types of labor and capital

For four of our sample countries, factor mobility was demonstrated at the level of two factors, labor and capital, but not at any further level of aggregation. This group was most diverse, consisting of the United States, Portugal, Brazil, and Russia. Again we stress that at the level of two factors, aggregate labor and capital, these countries exhibit factor mobility across industries. What we cannot confirm for these four countries is that educational level accurately captures marketplace premia. For the United States, at least, this finding is not inconsistent with recent work by Cappelli (2014) showing that increasing the number of college graduates is not the solution to skill shortages in US industries, and that the US is in fact now facing a problem of over-education.

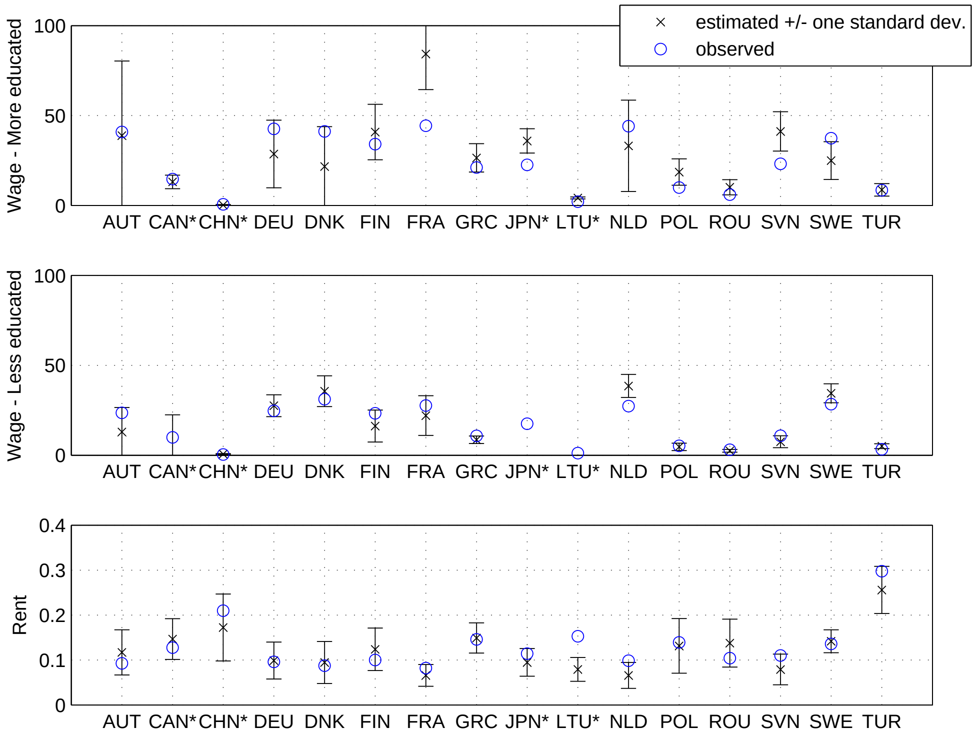

Figure 6: Sixteen countries with three mobile factors in 2005: two types of labor and capital

Note: For all countries except Canada, China, Japan, and Lithuania, more educated labor is college and less educated is elementary and high school. For Canada, China, Japan, and Lithuania, indicated by *, more educated is college and high school, and less educated is elementary school.

5.3 Countries whose factors are immobile in 2005

Factor immobility implies that factor earnings in specific sectors can be higher or lower than the economy-wide average earnings. Whatever the underlying cause of immobility, the logic of competitive markets argues that these differentials would be bid away if factors could move freely between sectors. What is less clear is how to gage these industry differentials since all industries employ different combinations of both capital and labor. The coefficients of variation of wages and rents, taken separately, do not reflect the full industry cost structure nor do they allow an easy identification of which industries deviate the most from "normal costs".

We are able to approximate normal costs since we have detailed information on the underlying factor usages in each sector. Let D be the $n \times f$ matrix of direct inputs per dollar of gross output. We use D rather than V, which records direct and indirect factor usage, because once we acknowledge factor immobility we can no longer aggregate factors in different sectors. Consider industry i whose direct factor costs per unit are given by $d_{iL}w_i + d_{iK}r_i$, where d_{if} is the direct input requirement for labor (subscript L) or capital (subscript K), paid at the industry specific wage, w_i, and rent, r_i, respectively. This factor cost is observed in the data as value-added per unit of gross output in sector i. The hypothetical normal cost of a unit in industry i is given by $d_{iL}w + d_{iK}r$, where we have simply replaced industry specific payments with economy-wide average payments to labor, w, and capital, r. The ratio of these two measures of unit cost indicates whether an industry has abnormally high or abnormally low factor costs; in the discussion that follows we refer to this comparison as the immobility ratio.

Our null hypothesis of factor mobility is rejected for 14 out of 40 countries, and in these 14 countries we would expect to find evidence that at least some industries have unusually high or low direct unit costs. In this large international sample, there is no *a priori* indication of which or how many industries may have abnormal costs. Figure 7 depicts the immobility ratio for several countries, each compared to a similar country with mobile factors. Indonesian stands out as a case where several industries, including mining (sector 2), refined petroleum products (sector 8), and transport equipment (sector 15), have extremely high costs. While the comparison country China exhibits some variation in the immobility ratio, it was not sufficient to reject the null hypothesis of factor mobility.

The two other comparison pairs depicted in Figure 7, Korea and Taiwan and Germany and Ireland, show a more typical degree of industry variability. For those 14 countries which had immobile factors, on average 2.4 industries were outliers in the sense that the immobility ratio was either greater than 3 or less than 0.3. Among those 26 countries with mobile factors, the average number of industries falling outside this range was equal to 1.2. Comparing Ireland to Germany, we see that in 2005 Ireland had extremely high costs in the finance sector (sector 28) but extremely low costs in the real estate sector (sector 29). Perhaps this was an as yet unnoticed harbinger of the coming financial collapse.

5.4 Change in mobility over time and the coefficient of variation

Prior to this study, one of the most commonly used indicators of factor mobility was the coefficient of variation of the factor payment. The simple logic of this measure is that if workers in a given country earn high wages in some sectors and low wages in other sectors, there will be a high coefficient of variation of wages in this country, interpreted as an indication of low factor mobility. While the intuition is appealing, it is difficult to know what the cut-off level of wage dispersion is for immobile factors or whether the cut-off level is the same in different countries. Another limitation of past work is that it has been based on a small group of countries and a limited number of sectors, with sporadic measures over time. Our data allow for a rich analysis of the patterns in the coefficient of variation across a wide range of sectors, including both manufacturing and service industries, in many countries. The two panels of Figure 8 depict the coefficient of variation in the year 2005 of the rent (left panel) and the wage (right panel) against GDP per capita in our 40 sample countries. Each measure for each country shows the variability of the factor payment across 35 sectors. We see that in all countries, the rental rate is more highly dispersed than the wage. Also, low income countries tend to have greater dispersion of wages, although this tendency is not nearly as pronounced for the rental rate. However, there is no obvious correlation between countries with immobile factors and level of economic development, since these 14 countries are spread across the GDP per worker spectrum.

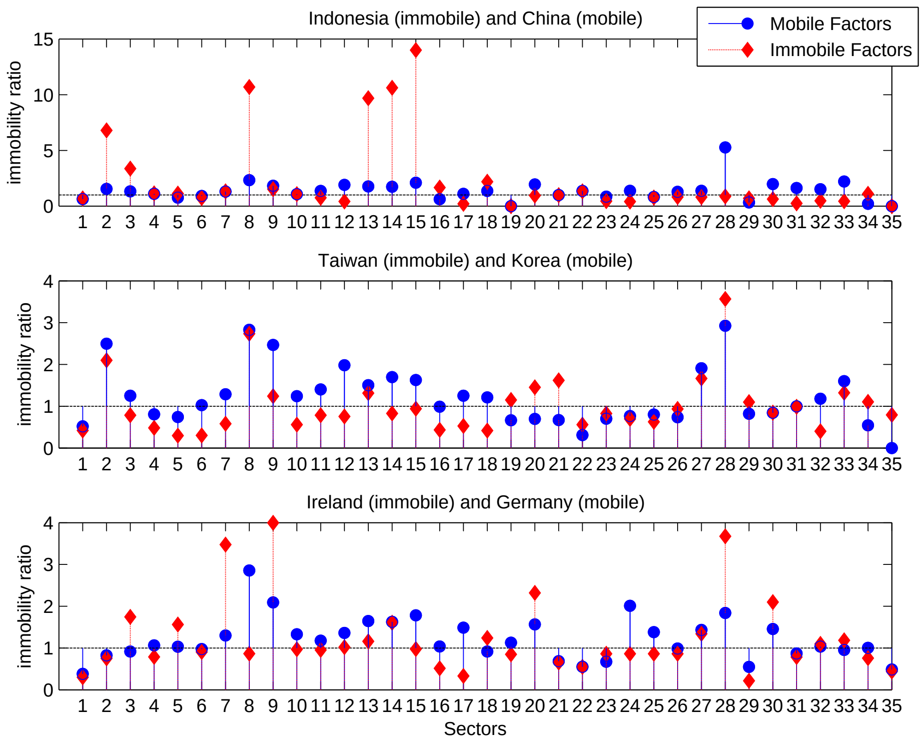

Figure 7: A comparison of select countries whose factors are mobile to those whose factors are immobile in 2005

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.

Since we can only measure one coefficient of variation per factor per country, we extend our analysis to two prior years, 1995 and 2000, giving us 120 observations for each factor.[5] We also repeat our two factor test for mobility for the years 1995 and 2000. We find the set of countries for which the null hypothesis is accepted is highly stable. Of the 24 countries that showed factor mobility in 2005, 19 showed the same result for all three years of observation. For the 16 countries for which the null hypothesis of factor mobility was rejected in the year 2005, 7 had the same result for all three years and an additional 6 countries the null hypothesis was rejected in one of the prior two years.

We perform two simple statistical tests that evaluate the coefficient of variation in comparison to our test of factor mobility. First we assign countries to two groups according to our

[5]Input-output tables are benchmarked to census years. The pattern and frequency of these benchmark years varies over the sample, so no little new information is likely from more frequent observations. Likewise, the pattern of wages across industries for different skill groups is highly correlated, so we report only average wages.

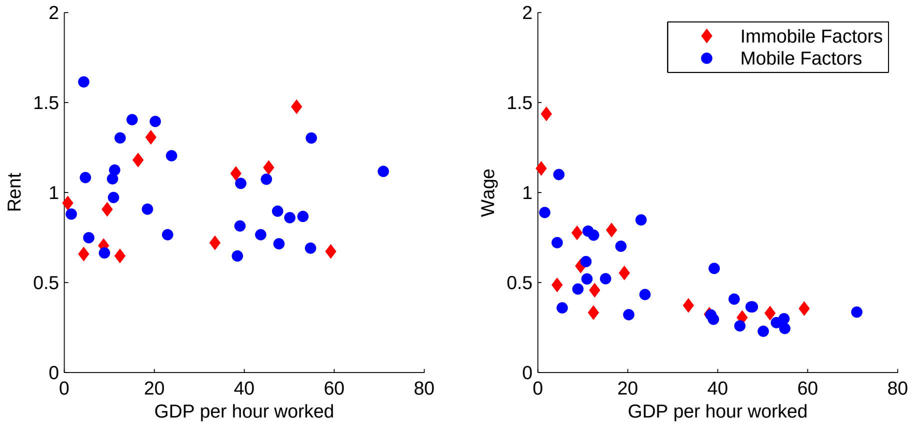

Figure 8: The coefficient of variation of wages and rents in 40 countries in 2005

Note: Countries are identified as mobile or immobile based on our Wald test results. Slovakia's coefficient of variation of rent, equal to 10.3, was omitted from the left panel.

results: those 19 countries whose factors are mobile in all three years of observation those 7 countries whose factors are not mobile in all three years. We then do a simple t-test on the two groups' average coefficient of variation for each factor. There is no significant difference in the mean of the coefficient of variation for either factor.

One limitation of this test is that we are grouping together high and low income countries, whose coefficient of variation appears to differ for reasons not necessarily related to factor mobility. Hiscox focuses on how whether the coefficient of variation changes over time in a given country. Although most countries in our sample do not change from mobile to immobile, there are still 18 changes in state. We can use these changes to examine whether the coefficient of variation moves in the expected direction. Our second test compares the small set of countries who experience a change of state to those which do not. In the case of a change from immobile to mobile, the coefficient of variation would be expected to decrease, and in the case of a change from mobile to immobile it would be expected to increase. We compare the percent change in the coefficient of variation in these two groups to the percent change in the coefficient of variations of the group which experienced no change in state.

Table 1 presents the results of an analysis of variance (ANOVA) to test whether the mean change differs for each group. Again, we find no evidence that the transition from one state to another is associated with the expected change in the coefficient of variation. Looking at the results for wages, we are almost able to reject the null hypothesis that the group means are the

	Group 1 Not mobile to mobile	Group 2 No Change	Group 3 Mobile to not mobile	F-Stat	P-value
		Percent change in wage			
Mean	16.7	-.3	-11.0	3.08	0.052
St. dev.	13.4	23.5	19.5		
		Percent change in rent			
Mean	14.38	1.94	-4.22	0.27	0.76
St. dev.	18.05	54.31	34.27		
N	6	62	12		

Table 1: ANOVA test of mean percent change in coefficient of variation across 3 groups. Note: Observations are percent change from 1995 to 2000 and from 2000 to 2005

same. However the signs of the two groups which change state are opposite from the expected direction.

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 majority of countries, 26 out of 40, factors are mobile across sectors. 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.

However, in many countries, some industries exhibit unusually high or low cost structures, interpreted here as evidence of factor immobility. 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.

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

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