Factor Price Equalization in the UK? A General Test and Evidence∗

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Abstract

This paper tests for factor price equality across regional labor markets of the United Kingdom. The paper contributes to the theoretical literature on factor price equality by demonstrating that a comparison of relative wagebills can identify departures from factor price equality under very general assumptions about production, markets and unobserved differences in region-industry-factor quality. Even though the U.K. has characteristics favoring factor price equalization, e.g. its small area and high population density, we find significant variation in factor prices across regions. Consistent with the Heckscher-Ohlin trade model, we find a relationship between regions’ relative factor prices and their industrial structure.

Keywords: relative factor prices, industrial structure, Heckscher-Ohlin, regional wages

JEL classification: F11, F14, C14

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1. Introduction

Wage variation within and across countries is important for firms choosing where to locate, workers deciding where to live and governments managing regional development. Economic theory suggests that goods trade and factor mobility are two powerful mechanisms promoting factor price convergence. Because these forces are more powerful within countries than across them, factor price convergence is more likely to occur within an economy than internationally.

This paper tests for factor price equality across regional labor markets of the United Kingdom. We employ a test methodology that is robust to unobserved regional productivity differences, region-industry factor quality and composition differences, and variation in industry production technology. The U.K. is a particularly well-suited target for this test given its small geographic area and high population density, conditions which should strengthen the forces behind factor price convergence. In spite of these attributes, the U.K. exhibits statistically significant and economically meaningful variation in skill premia across regional labor markets. Our empirical results suggest that relative wages for skilled workers are one third lower in the South-East than in Wales or Scotland.

This paper also finds that differences in the relative return for skilled workers are correlated with variation in industrial structure. The more divergent are relative wages across regions, the fewer industries regions have in common. These results are consistent with the production implications of the Heckscher-Ohlin factor proportions framework, which has countries (or regions within countries) specializing in industries according to comparative advantage based on relative factor endowments. This variation in the industrial structure within the U.K. is significant because it signals a potential asymmetry in regional exposure to macroeconomic or international trade shocks.

This paper also offers a contribution to the theoretical literature on factor price equality. The basis of our test is a methodology developed by Bernard and Schott (2002) which controls for unobserved region-factor variation in factor quality by using data on relative wage bills. In this paper, we demonstrate that the wage-bill test can identify departures from factor price equality under very general assumptions regarding production and markets, including imperfect competition, increasing returns to scale, un-
observed region-industry-factor quality differences, and differences in factor composition.

Our empirical analysis relates to an existing line of research on earnings variation within the U.K.\footnote{See, for example, Cameron and Muellbauer (2000, 2001), Duranton and Monastiriotis (2002), HM Treasury (2001) and Jackman and Savouri (1991).} This literature examines absolute wage differences across regions, often in the context of Mincerian wage regressions. Here, we focus on differences in relative factor prices, which can be influential in determining the spatial variation of industrial structure. In addition, we identify departures from relative factor price equality across U.K. labor markets even after controlling for variation in factor quality and technology. Our study is also the first to examine the finely defined U.K. Postcode Areas, geographic regions that conform more closely to local labor markets than the relatively aggregate Administrative Regions used in prior work.

The paper is structured as follows. Section 2 summarizes the empirical methodology. Section 3 describes the data. Section 4 discusses the econometric specification, and Section 5 presents the empirical results. Sections 6 and 7 examine a number of potential explanations for the empirical finding of the failure of relative factor price equality. Section 8 concludes.

2. Relative Factor Price Equality

Factor price equality can be either absolute or relative. If absolute factor price equality holds, regions producing identical products for identical prices with identical technologies must have identical nominal factor rewards at a point in time. If relative factor price equality holds, regions producing identical products for identical prices must have identical relative factor rewards even though absolute factor prices may differ across regions due to variation in Hicks-neutral productivity. Our analysis focuses on relative factor price equality, henceforth referred to as RFPE. Note, however, that a failure of relative factor price equality indicates a failure of absolute factor price equality for at least one factor.

The existing literature has employed both direct and indirect methods to test for factor price equality. Direct tests examine whether raw or adjusted factor prices (or their dual) are equal across regions within countries.
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or across countries.\(^2\) Indirect tests typically are based upon the Heckscher-Ohlin trade model and infer the existence of factor price equality from the distribution of economic activity.\(^3\) If factors of production are immobile across regions or countries and relative endowments are sufficiently different, industries are allocated spatially according to comparative advantage: skill-abundant regions have relatively low skill premia and attract skill-intensive industries, while skill-scarce regions have high skill premia and attract unskilled–labor intensive industries.

In this paper we use a direct test of factor price equality developed by Bernard and Schott (2002). This methodology emphasizes the importance of unobserved variation in factor quality that cannot be directly measured by the econometrician and that biases traditional wage measures. Instead, the wage-bill test uses total payments to each factor, i.e. wage bills for payments to labor, to control for unobserved potential regional variation in factor quality. We show this test to be applicable under far more general conditions than those considered by the authors.

Bernard and Schott (2002) assume a constant-returns, constant elasticity of substitution (CES) industry production function which is common across regions under conditions of perfect competition. Factor quality is assumed to vary across regions and factors, complicating the identification of any region-specific deviations from relative factor price equality. We generalize the production technology, market structure, and form of unobserved factor quality variation and show the robustness of the relative wage bill test.

We begin with a value-added production function for industry \(j\) and region \(r\),

\[
Y_{rj} = A_{rj} F_j (N_{rj}, P_{rj}, K_{rj}),
\]


\(^3\)See, for example, Davis et al. (1997), Cunat (2001), Schott (2003) and Debaere and Demiroglu (2003).
where $A_{rj}$ is a region-specific, Hicks-neutral productivity shifter and $N_{rj}$, $P_{rj}$, and $K_{rj}$ are quality-adjusted inputs of skilled workers, unskilled workers and capital, respectively. The production function is common across regions for each industry, and firms in region $r$ and industry $j$ choose factor usage to minimize costs,

$$\min_{N_{rj},P_{rj},K_{rj}} w^P_r P_{rj} + w^N_r N_{rj} + w^K_r K_{rj}$$

such that

$$A_{rj} F_j (N_{rj}, P_{rj}, K_{rj}) = Y_{rj}$$

which defines the total cost function,

$$B_{rj} = A_{rj}^{-1} \Gamma_j (w^P_r, w^N_r, w^K_r) Y_{rj}$$

In this specification, firms may act either as price-takers in product markets (perfect competition; this section) or choose prices subject to a downward sloping demand curve (imperfect competition; next section). Although the main exposition here assumes constant returns to scale, a later section introduces increasing returns to scale and discusses the implications for relative factor prices. In factor markets, we assume that firms choose employment taking factor prices as given. Though we write down the model with three factors of production, the analysis can be extended to an arbitrary number of industries or factors.

Let a tilde ($\tilde{}$) signify quantities that have not been adjusted for quality, and let $\theta^\varphi_{rj}$ denote a quality adjustor for industry $j$, region $r$ and factor $\varphi$. Thus, we allow for unobserved variation in quality that is specific to factors, regions and industries. The quality-adjusted employment level and wage of factor $\varphi \in \{P, N, K\}$ in region $r$ equals the product of the quality adjustor and the observed quantity, i.e.

$$\varphi_{rj} = \theta^\varphi_{rj} \varphi_{rj} \quad \text{and} \quad w^\varphi_{rj} = \tilde{w}^\varphi_{rj} / \theta^\varphi_{rj}.$$
Without loss of generality, assume there are two regions, \( r \) and \( s \), where region \( s \) is the reference region whose factors are taken to be the baseline quality benchmarks, i.e. \( \theta_{sj}^r = 1 \).

The demand for quality-adjusted factor \( \varphi \) may be obtained using Shephard’s Lemma,

\[
\varphi_{rj} = A_{rj}^{-1}Y_{rj} \frac{\partial \Gamma_j(\cdot)}{\partial w_r^j}.
\]  

(5)

Dividing one first-order condition by another provides an expression for the relative demand for any two quality-adjusted factors of production. The relative demand for skilled workers in terms of unskilled workers is

\[
\frac{N_{rj}}{P_{rj}} = \frac{\partial \Gamma_j(\cdot)}{\partial w_r^j} / \frac{\partial \Gamma_j(\cdot)}{\partial w_r^N}.
\]  

(6)

Using the relationship between quality-adjusted and observed values in (4), this implies the following relative demand for observed factors of production,

\[
\frac{\tilde{N}_{rj}}{\tilde{P}_{rj}} = \frac{\theta_{rj}^P}{\theta_{rj}^N} \frac{\partial \Gamma_j(\cdot)}{\partial w_r^P} / \frac{\partial \Gamma_j(\cdot)}{\partial w_r^N}.
\]  

(7)

Under the null of relative factor price equality, quality-adjusted relative wages and factor usage across regions \( r \) and \( s \) must be equal,\(^5\)

\[
\frac{w_r^N}{w_r^P} = \frac{w_s^N}{w_s^P} \quad \text{and} \quad \frac{N_r}{P_r} = \frac{N_s}{P_s},
\]  

(8)

where the latter equation follows directly from equation (6).\(^6\)

Observed relative wages and observed factor usage in the two regions under the null of RFPE, on the other hand, are given by,

\[
\frac{\tilde{w}_r^N}{\tilde{w}_r^P} = \frac{\theta_{rj}^N}{\theta_{rj}^P} \frac{\tilde{w}_s^N}{\tilde{w}_s^P} \quad \text{and} \quad \frac{\tilde{N}_{rj}}{\tilde{P}_{rj}} = \frac{\tilde{N}_{sj}}{\tilde{P}_{sj}} / \theta_{rj}^P.
\]  

(9)

\(^5\)RFPE holds if the quality-adjusted relative wages (or relative input demands) are equal for any \( M - 1 \) of the \( M \) factors of production.

\(^6\)Homogeneity of degree one of the cost function implies that the derivatives \( \partial \Gamma_j / \partial w_r^j \) are homogenous of degree zero in factor prices. It follows immediately from equation (6) that, with identical quality-adjusted relative factor prices, regions will employ quality-adjusted factors of production in the same proportions.
These relationships demonstrate the difficulty of using observed wages to test for factor price equality: even under the null hypothesis of RFPE, observed relative wages can vary across regions if there are differences in unobserved industry-factor quality (i.e. \( \theta_{rj}^N \neq 1 \) or \( \theta_{rj}^P \neq 1 \)). Bernard and Schott (2002) solve this problem by combining observed wages and employment into wage bills, where the wage bill for factor \( \varphi \) is equal to \( w_{rj}^\varphi \varphi_{rj} \). As is evident from equation (9), multiplying wages and employment causes region-factor quality adjustors to drop out. As a result, relative wage bills, which are generally available to the researcher, are equal under the null hypothesis of relative factor price equality,

\[
(H_0: \text{RFPE}) \quad \frac{\text{wagebill}_{rj}^N}{\text{wagebill}_{rj}^P} = \frac{\text{wagebill}_{sj}^N}{\text{wagebill}_{sj}^P}. \tag{10}
\]

If RFPE does not hold, the quality-adjusted relative \( N/P \) wage differs across regions \( r \) and \( s \) by a multiplicative factor, \( \gamma_{np}^rs \). Here, again, we let region \( s \) be the benchmark region, so that \( \gamma_{np}^rs = \gamma_{np}^r/s \), where \( \gamma_{np}^s = 1 \). With quality-adjusted relative wage differences across regions, factor usage also varies. Under the alternate hypothesis of no RFPE,

\[
(H_1: \text{No RFPE}) \quad \frac{\text{wagebill}_{rj}^N}{\text{wagebill}_{rj}^P} = \eta_{rsj} \frac{\text{wagebill}_{sj}^N}{\text{wagebill}_{sj}^P}, \tag{11}
\]

where

\[
\eta_{rsj} = \gamma_{rs}^{NP} \left[ \frac{\partial \Gamma_j(\cdot)/\partial w_{rj}^N}{\partial \Gamma_j(\cdot)/\partial w_{rj}^P} \right] \left[ \frac{\partial \Gamma_j(\cdot)/\partial w_{sj}^P}{\partial \Gamma_j(\cdot)/\partial w_{sj}^N} \right], \tag{12}
\]

where the terms inside the brackets represent differences in relative factor usage and are also a function of \( \gamma_{rs}^{NP} \). For example, if the region-industry production function is CES with \( \sigma_j = 1/(1 - \rho_j) \) as the elasticity of substitution between factors, as in Bernard and Schott (2002), then,

\[
\eta_{rsj}^{NP} = \gamma_{rs}^{NP} \left[ (\gamma_{rs}^{NP})^{1/(\rho_j-1)} \right] = (\gamma_{rs}^{NP})\rho_j/(\rho_j-1). \tag{13}
\]

Together equations (10) and (11) provide the basis for a test of the null hypothesis of RFPE that is robust to unobserved region-industry variation.
in factor quality. In our empirical work below, we test whether $\eta_{rsj}^{NP} = 1$ across U.K. regions.

Note that $\eta_{rsj}^{NP} \neq 1$ is sufficient to reject RFPE, but not necessary. Under CES production, for example, even if $\gamma_{rs}^{NP} \neq 1$ (so that quality-adjusted relative wages are not equalized), the parameter $\eta_{rsj}^{NP} = (\gamma_{rs}^{NP})^{\rho_j/(\rho_j-1)}$ equals unity for the special case of a Cobb-Douglas production technology ($\rho_j = 0$). This is consistent with our empirical approach that focuses on sufficient conditions for the rejection of relative factor price equality. We test the null hypothesis $\eta_{rsj}^{NP} = 1$ and, in so far as this hypothesis is rejected, this is sufficient for us to reject RFPE. Indeed, under CES, the fact that $(\gamma_{rs}^{NP})^{\rho_j/(\rho_j-1)}$ is close to 1 for $\rho_j$ close to 0 actually makes it harder for us to reject the null hypothesis and strengthens any finding of a rejection of RFPE.

Factor price equalization is a prediction that all relative factor prices are equalized. A rejection of relative factor price equality for any pair of factors, e.g. skilled and unskilled labor, is sufficient to reject the null hypothesis of RFPE.7

In the remainder of this section, we demonstrate the robustness of the relative wage bill test to the existence of imperfect competition, to production exhibiting increasing returns to scale, and to differences in factor composition.

2.1. Imperfect Competition

If firms maximize profits subject to a downward sloping inverse demand curve, $v_{rj}(Y_{rj})$, under conditions of imperfect competition, the first-order condition for profit-maximization is

$$\frac{dv_{rj}(Y_{rj})}{dY_{rj}} Y_{rj} + v_{rj}(Y_{rj}) - \frac{\Gamma_j(\cdot)}{A_{rj}} = 0. \quad (14)$$

Defining the elasticity of demand as $\varepsilon_{rj}(Y_{rj}) \equiv -(dY_{rj}/dv_{rj})v_{rj}/Y_{rj}$, we obtain the standard result that equilibrium price is a constant mark-up

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7With perfect capital mobility, the rate of return to capital may be equalized across regions. However, as long as there is a degree of immobility for at least one other factor of production, quality-adjusted relative factor prices will generally vary.
over marginal cost,
\[ v_{rj}(Y_{rj}) = \left( \frac{\varepsilon_{rj}(Y_{rj})}{\varepsilon_{rj}(Y_{rj}) - 1} \right) \frac{\Gamma_j(\cdot)}{A_{rj}}. \]  
(15)

By Shephard’s Lemma, equilibrium demand for each quality-adjusted factor of production continues to be given by the derivative of the total cost function with respect to the factor price as specified in equation (5). The derivation of the test for relative factor price equalization is thus identical to that provided in the previous section.

2.2. External Economies of Scale

It is straightforward to introduce external economies of scale into the framework above in either perfectly or imperfectly competitive market structures. External economies of scale correspond to the assumption that technical efficiency in a region-industry is a function of scale. In the most general case, we have,
\[ A_{rj} = A_{rj}(Y_{rj}, Y_{r,-j}, Y_{-r,j}, Y_{-r,-j}) \]  
(16)

where \( Y_{r,-j} \) is the vector of outputs in all other industries in a region, \( Y_{-r,j} \) is the vector of all other regions outputs in the industry, and \( Y_{-r,-j} \) is the vector of all other regions outputs in all other industries. Because the cost-minimization behavior of the firm is the same (see equation 2), the derivation of the test for relative factor price equality remains unchanged.

2.3. Internal Economies of Scale

Internal economies must clearly be combined with imperfect competition. Under internal economies of scale, the cost function (3) is no longer linearly homogenous of degree one in output. Equilibrium price continues to be a constant mark-up over marginal cost,
\[ v(Y) = \left( \frac{\varepsilon(Y)}{\varepsilon(Y) - 1} \right) \frac{1}{A_{rj}} \frac{\partial \Gamma_j(w^P_r, w^N_r, w^K_r, Y)}{\partial Y}. \]  
(17)

Equilibrium demand for quality-adjusted factors of production may again be obtained using Shephard’s Lemma. Using the relationship between
quality-adjusted and non quality-adjusted values, relative demand for observed non-production and production workers will be given by,

\[
\frac{N}{P} = \frac{\theta^P_{rj} \partial \Gamma_j(w^P_r, w'^N_r, w^K_r, Y)/\partial w^N_r}{\theta^{N}_{rj} \partial \Gamma_j(w^P_r, w'^N_r, w^K_r, Y)/\partial w^P_r}. \tag{18}
\]

Multiplying the expressions for observed relative factor prices and observed relative employments, the terms in unobserved factor quality will again cancel. The expression for relative wage bills now becomes,

\[
\frac{\tilde{\text{wagebill}}^N_{rj}}{\tilde{\text{wagebill}}^P_{rj}} = \gamma^{NP}_{rs} \left( \frac{\partial \Gamma_j(\cdot)/\partial w^N_r}{\partial \Gamma_j(\cdot)/\partial w^P_r} \right) \left( \frac{\partial \Gamma_j(\cdot)/\partial w^P_s}{\partial \Gamma_j(\cdot)/\partial w^N_s} \right) \frac{\tilde{\text{wagebill}}^N_{sj}}{\tilde{\text{wagebill}}^P_{sj}}. \tag{19}
\]

In the standard case in the theoretical literature on trade under internal economies of scale, firms within an industry face the same constant elasticity of substitution \( \varepsilon_j \), cost functions are homothetic and identical within industries, and there is free entry so that price equals average cost. Combining free entry with the pricing relationship in (17), the equilibrium ratio of average to marginal cost will equal a constant \( \varepsilon_j/(\varepsilon_j - 1) \), which with homothetic cost functions defines a unique equilibrium value of output for all firms in the industry.

Under the null hypothesis of factor price equalization, \( \gamma^{NP}_{rs} = 1 \), and with all firms in the industry facing the same factor prices and producing the same output, the terms in parentheses in (19) cancel, so that we again obtain the prediction that relative wage bills are equalized under the null.\(^8\)

More generally, in the presence of internal economies of scale, variation in firm size across regions and industries provides an explanation for the failure of relative factor price equality.

2.4. Factor Quality and Factor Composition

To develop the implications of variation in factor composition, we assume that the production technology is weakly separable in non-production and production workers. Firms first choose optimal quantities of non-production and production workers, before choosing optimal amounts of

\(^8\)See Helpman and Krugman (1985) for an analysis of theoretical models of monopolistic competition and increasing returns to scale where there is factor price equalization.
different worker types within these categories. With this assumption (and a linear homogeneity restriction imposed below), the terms in unobserved factor quality \((\theta^N_{nj}, \theta^P_{pj})\) also control for region-industry variation in the composition of non-production and production workers.\(^9\)

Without loss of generality, we demonstrate the point formally for skilled workers where there are only two types (managers and engineers). Suppose the quality-adjusted flow of non-production labor services is a function of the quality-adjusted flow of labor services supplied by managers and engineers:

\[
N = \phi(N_1, N_2) \\
= \phi \left( \frac{N_1}{(N_1 + N_2)}, \frac{N_2}{(N_1 + N_2)} \right) (\tilde{N}_1 + \tilde{N}_2) \\
= \phi \left( \theta^{N_1, \tilde{n}_1}, \theta^{N_2, \tilde{n}_2} \right) \tilde{N}
\]

where \(N\) is quality-adjusted non-production labor services, \(N_1\) is quality-adjusted manager labor services, \(N_2\) is quality-adjusted engineer labor services, \(\phi(\cdot)\) is assumed to be linearly homogenous of degree one, \(\tilde{N} = \tilde{N}_1 + \tilde{N}_2\) is the observed number of non-production workers, and \(\tilde{n}_1\) and \(\tilde{n}_2\) are observed shares of engineers and managers in non-production employment. Equation (20) may be re-written more compactly as:

\[
N = \tilde{N}/\theta^N, \quad \theta^N = \phi \left( \theta^{N_1, \tilde{n}_1}, \theta^{N_2, \tilde{n}_2} \right)
\]

where the term for the unobserved quality of non-production workers \((\theta^N)\) captures the unobserved quality of managers \((\theta^{N_1})\), the unobserved quality of engineers \((\theta^{N_2})\), and the composition of non-production workers between managers and engineers \((\tilde{n}_1, \tilde{n}_2)\).

The quality-adjusted wage of non-production workers is now a price index, defined as the dual to equation (20):

\[
w^N = \psi(w^N_1, w^N_2)
\]

where \(w^N_1\) is the quality-adjusted wage of managers and \(w^N_2\) is the quality-adjusted wage of engineers.

\(^9\)To simplify notation, we suppress region and industry subscripts throughout this section.
Expenditure on quality-adjusted non-production worker services is equal to observed expenditure on non-production workers:

\[ w^N N = \bar{w}^N N \]  

(23)

where \( w^N \) is the price index defined above and \( \bar{w}^N \) is the observed wage per non-production worker. It follows that the quality-adjusted non-production worker price index and the observed non-production worker wage are related according to:

\[ w^N = \frac{\bar{w}^N}{\theta^N}, \quad \theta^N \equiv \phi(\theta^N \bar{n}_1, \theta^N \bar{n}_2) \]  

(24)

The derivation of the relative factor price test remains unchanged. Under the null hypothesis that the quality-adjusted relative wage of non-production and production workers (\( w^N / w^P \)) is equalized across regions, the ratio of the observed wage bills of non-production and production workers must be equalized across regions. Thus, as well as allowing for variation in factor quality, the wage bill test also controls for differences in factor composition that are specific to regions and industries.

3. Data Description

Our data source is the United Kingdom’s Annual Respondents Database (ARD). This dataset includes basic information on the population of establishments in the manufacturing sector from 1980 to 1998, including employment, location, ownership, and industry.\(^{10}\) More detailed information on output, investment, intermediate inputs, employment, and wages is available for a subset of these establishments. This subset of roughly 13,000 establishments per year encompasses all establishments with more

\(^{10}\)ARD establishments correspond roughly to a ‘line of business’. Establishments are potentially more disaggregate than firms, i.e. some firms are single establishments while others consist of several establishments. Establishments are more aggregate than plants, i.e. some establishments consist of a single plant, while others include several. As a result, an establishment’s plants may be located in more than one region. Such overlap reduces spatial variation in wages, employment, and wage bills in our data, making it more difficult to reject the null hypothesis of RFPE. As a check on the empirical results, we perform several robustness tests in section 5.2.
than 100 employees plus a sample of smaller establishments. Because our methodology requires information on wages and employment, we work with the sampled data. After presenting our findings, we demonstrate that our results are not driven by any resulting sample selection bias.

Labor in the ARD is can be broken down into two categories: Administrative, Technical, and Clerical Workers (i.e. non-production workers) and Operatives (i.e. production workers). Following the labor market literature (e.g. Berman et al. 1998), we take non-production and production workers to represent high- and low-skill workers, respectively. A key advantage of our test for factor price equality is that it controls for unobserved region-industry variation in both the quality and composition of these worker categories.

Each ARD establishment can be associated with one of approximately 200 four-digit U.K. 1980 Standard Industrial Classification (SIC) industries. The relatively disaggregate level at which production is recorded is an advantage for our analysis as it mitigates the possibility that a violation of RFPE is due to unobserved within-industry variation in product mix.

We examine spatial variation in relative wages, employment, and wage bill levels at two levels of geographical disaggregation. First, we consider 10 Administrative Regions of the United Kingdom. This enables us to analyze the broad pattern of spatial variation and allows the results of our methodology to be compared with existing studies which have focused on Administrative Regions. Second, we examine variation across Postcode Areas which number more than 100 and are listed in Table 1. These regions are centered around cities and major towns and roughly correspond to commuting patterns and local labor market areas.

\footnote{For the years that we consider (1992 and 1986), the sampling threshold is 100 employees. The sample represents roughly 75% of manufacturing employment. The ARD contains information on production activity only; other non-production activities such as headquarters services and research and development (R&D) are excluded. For further discussion of the ARD data, see Devereux et al. (1999), Disney et al. (2000), Duranton and Overman (2002) and Griffith (1999).}

\footnote{An Administrative Region in the U.K. is a large geographic entity such as Scotland or Wales. Northern Ireland is excluded from the analysis because the data are collected separately and there is only one Postcode Area for the entire of Northern Ireland.}

\footnote{We aggregate the 8 postcode areas in Central London to form a single geographical region, as is consistent with commuting patterns.}
while they are in the same Administrative Region. These data provide a rich source of information on spatial variation in factor prices within the United Kingdom.

Information on Postcode Areas is only available in the ARD from 1985 onwards; separate data on non-production and production workers ceases to be collected after 1995; and there is a change in the U.K. SIC system after 1992. Therefore, in our baseline specification, we consider the year 1992 while we also report results for 1986 as a robustness check. To the extent that we find persistent differences in quality-adjusted relative wages across U.K. regions for years that are at such different stages of the U.K. business cycle, we have evidence of systematic departures from RFPE that are not driven by idiosyncratic shocks to regions or business cycle fluctuations.

Because establishments are subject to idiosyncratic shocks, measurement error in establishment-level data may be large for any one year. As a result, we aggregate establishments to industries in each region in our regression analysis. We exclude all industries classified as ‘other manufacturing’ since these are explicitly heterogeneous categories and may include different sub-industries in different regions. The null hypothesis of RFPE predicts the equalization of relative wage bills across regions within each four-digit industry. This yields approximately 1,400 region-industry observations for Administrative Regions and over 5,000 region-industry observations for Postcode Areas.

Other potential datasets that might be used to analyze regional variation in relative wages within the United Kingdom are the Labour Force Survey (LFS) and New Earnings Survey (NES). Both these datasets collect information on individuals, including wages, location, industry and a variety of demographic characteristics which proxy for individual skill levels. To evaluate relative factor price equality across regions with a single year of this type of data, one would typically estimate a form of a Mincerian wage regression allowing the coefficients on the skill proxies to vary by industry and region. Under RFPE, the coefficients on the skill proxies must be equal across regions within an industry.

In light of these factors, both U.K. data sources have a number of shortcomings from the point of view of testing for regional factor price differences. First, each survey uses a sampling frame which is not representative at the region-industry level (for example, the NES is a one per cent na-
tionwide sample of employees with income levels such that they are part of the PAYE income tax scheme). This means that the sample of workers is not necessarily random within region-industry cells, giving rise to potentially spurious rejections of relative factor price equality. Second, because the LFS and NES are surveys, cell sizes become extremely small once one simultaneously conditions on region, industry and skill, especially for the kinds of disaggregated regions and industries one would hope to use. Third, only the LFS has information on educational attainment which might be thought of as a more direct measure of skill (the NES uses an occupation-based measure of skill as in the ARD). However, the LFS does not simultaneously report information at a fine level of both geographical and industrial disaggregation. For example, some versions of the LFS have information on four-digit industries, but only for aggregate regions corresponding roughly to the level of Administrative Regions. More geographical detail is available in the Local Area LFS data, but only for highly aggregated industries.

4. Econometric Specification

In Section 2 we showed that under the null of RFPE the ratio of the non-production workers’ wage bill to the production workers’ wage bill is the same across regions within an industry. This implies that, for an industry \( j \), each region’s relative wage bill equals the value for any base region \( s \) and, in particular, for the United Kingdom as a whole,

\[
\frac{\text{wagebill}_{nj}^N}{\text{wagebill}_{nj}^P} = \frac{\text{wagebill}_{sj}^N}{\text{wagebill}_{sj}^P} = \frac{\text{wagebill}_{UKj}^N}{\text{wagebill}_{UKj}^P}.
\]

(25)

The simplest test of the null hypothesis is therefore to regress the ratio of wage bills for region \( r \) relative to the ratio for the U.K. as a whole on set of region dummies,

\[
\ln \left( \frac{\text{RW}B_{rj}^{NP}}{\text{RW}B_{UKj}^{NP}} \right) = \sum_r \alpha_r^{NP} d_r + \varepsilon_{rj}^{NP}
\]

(26)

where \( \text{RW}B_{rj}^{NP} \) denotes the relative wage bill in industry \( j \) and region \( r \) for non-production workers and production workers (\( \text{RW}B_{rj}^{NP} = \text{wagebill}_{rj}^N / \text{wagebill}_{rj}^P \)).
Factor Price Equalization in the UK?

\( \text{wagebill}_{ij}^p \): \( R W B_{UK}^{NP} \) is the corresponding relative wage bill for the U.K. as a whole; and the \( \alpha_r^{NP} \) correspond to the coefficients on the regional dummies \( d_r \). When defining the relative wage bill for the U.K. as a whole, we exclude the own region \( r \). Under the null hypothesis of RFPE, \( \alpha_r^{NP} = 0 \) for all regions and factor pairs, and a test of whether the \( \alpha_r^{NP} \) are jointly equal to zero therefore provides a test of RFPE.

The regression in equation (26) corresponds to a differences in means test. We choose the aggregate U.K. as a base region and test RFPE by comparing the relative wage bill for an industry \( j \) across all regions \( r \) to the value for the U.K. as a whole in the same industry.

We also test RFPE by allowing individual regions to be the base region. That is, we begin by choosing a region \( s \) to be the base (where \( \gamma_s^{NP} = 1 \)) and run a regression to analogous equation (26),

\[
\ln \left( \frac{R W B_{rj}^{NP}}{R W B_{sj}^{NP}} \right) = \sum_r \alpha_{rs}^{NP} d_r + \varepsilon_{rsj}^{NP}.
\]

(27)

A test of whether the \( \alpha_{rs}^{NP} \) are jointly equal to zero provides a test of the null hypothesis of RFPE. Rejecting \( \alpha_{rs}^{NP} = 0 \) is sufficient to reject the null hypothesis of RFPE, and any pair of regions \( r \) and \( r' \) face the same relative factor prices if \( \alpha_{rs}^{NP} = \alpha_{r's'}^{NP} \). To avoid having the results driven by the choice of the base region, we estimate equation (27) for all possible choices of base region \( s \).

Although regions have the same relative wage bills under the null hypothesis of RFPE (hence \( \alpha_{rs}^{NP} = 0 \)), the theoretical analysis of Section 2 suggests that, under the alternative hypothesis, the coefficient on the regional dummies (\( \eta_{rs}^{NP} \) in equation 11 and \( \alpha_{rs}^{NP} \) in equations 26 and 27) may vary across industries. With a constant elasticity of substitution (CES) production technology, this cross-industry variation is associated with different elasticities of substitution between skilled and unskilled workers (equation 13).

We have no strong priors on the industry variation in the elasticity of substitution between different types of labor or in other features of the operator \( \Gamma_j \) in the cost function (equation 3), and therefore we pool observations across industries. Since under the null hypothesis, \( \alpha_{rsj}^{NP} = 0 \), holds for all industries \( j \), a finding of statistically significant coefficients on the regional dummies when pooling observations is sufficient to reject RFPE.
Our test for relative factor price differences holds for any constant returns to scale production technology. However, if we are willing to assume a CES production technology and choose a value for the elasticity of substitution \( \sigma \), the estimated coefficients on the regional dummies may be used to derive implied quality-adjusted relative wage differences across regions via equation (13). Comparing these estimates of quality-adjusted wage differences with actual values for relative wages, we can also derive implied differences in the relative quality of skilled and unskilled workers across regions and industries (\( \theta^N_{rj}/\theta^P_{rj} \) in equation 9).

For a given value of the elasticity of substitution between skilled and unskilled workers, we are thus able to obtain estimates of the extent to which actual relative wage differences across regions correspond to true differences in quality-adjusted relative wages or are instead explained by unobserved variation in factor quality.

Note that equations (26) and (27) compare the relative wage bill for non-production and production workers in region \( r \) to the value in a base region within each industry \( j \). This is a ‘difference in differences’ specification with a number of attractive statistical properties. Any industry-specific determinant of relative wage bills that is common across regions is ‘differenced-out’ when we normalize relative to the base region on the left-hand side of the equations (for example, features of the production technology, compensating differentials across industries, other inter-industry wage differentials, and industry-specific labor market institutions such as the degree of unionization). The analysis thus explicitly controls for observed and unobserved heterogeneity in the determinants of relative wage bills across industries.

Similarly, in both region \( r \) and the base region we analyze the wage bill of non-production workers relative to production workers. Therefore, any region-specific determinant of wage bills that is common to both non-production and production workers is ‘differenced-out’ when we construct a region’s relative wage bill (\( RW_{rj}^{NP} = \text{wage bill}^N_{rj} / \text{wage bill}^P_{rj} \)). Here potential examples include neutral regional technology differences and compensating differentials across regions.
5. Empirical Results

5.1. Baseline Specification

We begin by presenting the estimation results using the U.K. as the base region. We first report the results for Administrative Regions, followed by those for Postcode Areas. Table 2 reports the estimated differences in log relative wage bill ratios for Administrative Regions in 1992 and 1986. In both years, we reject the equality of the coefficients and thus reject RFPE.

In 1992 at the 5% significance level, we find 1 rejection above zero (for the South-East of England) and 5 rejections below zero (for the East Midlands, Yorkshire & Humberside, Northern, Wales, and Scotland). The results for 1986 display a similar pattern. At the 5% significance level, we again find 1 rejection above zero for the South-East of England, and there are again 5 rejections below zero, with the West Midlands replacing the East Midlands.

Whether the estimated values of the dummies correspond to higher or lower quality-adjusted relative wages of skilled workers depends on the operator $\Gamma_j$ in the cost function. With a CES production technology, a positive coefficient corresponds to a lower quality-adjusted relative skilled wage if $0 < \rho < 1$ (see equation 13). These values of $\rho$ imply an elasticity of substitution between skilled and unskilled workers greater than unity (i.e. $\sigma > 1$), which is consistent with typical empirical estimates in the labor literature (see in particular Katz and Autor 1999 and Katz and Murphy 1992).

Table 3 reports implied quality-adjusted relative skilled wages for $\sigma = 2$ in 1992. We find that the skill-abundant region (here the South-East, which includes London) is characterized by a lower equilibrium value of the relative wage of skilled workers, while skill-scarce regions (such as Wales and Scotland) have higher equilibrium values of the relative skilled wage. For comparison, Table 3 also reports a region’s average observed relative skilled wage expressed as a ratio of the average for the U.K. as a whole. Even looking at observed relative wages, we find that the South-East tends to have a lower relative skilled wage, while Wales and Scotland tend to have higher relative skilled wages.\(^{14}\) The differences in actual relative wages are

\(^{14}\)Re-estimating the specifications in equations (26) and (27) using actual relative wages rather than wage bills, we again find statistically significant departures from relative...
smaller than those in quality-adjusted relative wages, implying that the relative quality of non-production workers is higher in the South-East than in Wales or Scotland. This difference is consistent with economic priors.

Regression results for Postcode Areas in 1992 and 1986 are presented in Tables 4 and 5. Again, we can easily reject the null hypothesis of relative factor price equality in both years. As indicated in the tables, 32 of 111 regions reject factor price equality at the 10% level in 1992. Of these, 9 reject above zero and 23 reject below zero. Table 4 reports the estimated dummies for those Postcode Areas that reject above zero. These are concentrated exclusively in the South-East of England close to the M25, M4 highway corridor, and the area around Cambridge (see Figure 3).

Results for 1986 display a similar pattern: 34 regions reject factor price equality at the 10% level of significance, with 7 rejecting above zero and 27 rejecting below zero. Four of the rejections above zero are the same Postcode Areas as in 1992. The emergence of Cambridge as a high relative wage bill region in 1992 is consistent with the recent development of a cluster of skill intensive information technology and biotechnology industries in the area.

Tables 4 and 5 also report implied quality-adjusted relative wages for $\sigma = 2$. Figures 1 and 2 display the geographical distribution of the estimated coefficients for Administrative Regions and Postcode Areas respectively in 1992. The figures separate three groups of regions: those with positive and statistically significant coefficients representing regions with relatively low skill premia (indicated by the dark shading); those with negative and significant coefficients representing regions with high relative wages (corresponding to the intermediate shading); and those with statistically insignificant estimated values of the dummies (light or no shading). Both figures show a clear concentration of regions with positive estimated values (low quality-adjusted skill premia) in the South-East of England.

We also allow each Administrative Region and each Postcode Area to serve as the base region and then run the bilateral regression specified in equation (27). Given the large number of coefficients in each regression and the large number of regressions, we report a summary of the results in Table 6.\textsuperscript{15} For all base regions, for both Administrative Regions and factor price equalization in both years.

\textsuperscript{15}Overall, there are 90 and 12,210 possible bilateral rejections for Administrative Re-
Postcode Areas, and in both 1992 and 1986, the null hypothesis of RFPE is easily rejected at the 1% level with an F-test.

For Postcode Areas in 1992, 17% of the region-pairs reject relative factor price equality at the 10% level, while 11% reject at the 5% level. Every region rejects with at least 6 other regions. In 1986, 19% (12%) of the region pairs reject relative factor price equality at the 10% (5%) level. Every region rejects with at least 5 other regions at the 10% level. For Administrative Regions, we find that 57% of region-pairs reject at the 10% level in 1992 and 40% in 1986. This corresponds to an average number of rejections against 5 and 4 Administrative Regions respectively, making clear that the rejection of RFPE is not simply driven by the South-East of England. Every region rejects with at least 2 other regions at the 10% level in both years.

In every specification, the null hypothesis of relative factor price equality is rejected for the U.K.. Moreover, the results are consistent across years, definitions of regions, and choice of the base region; the skill-abundant South-East labor markets have lower quality-adjusted wage premia for skilled workers while the skill-scarce regions of the north have relatively high skill premia.

5.2. Robustness

The results are robust across a variety of econometric specifications and to a number of dataset refinements. Robustness results are reported in Table 7. To conserve space, we check for robustness using data for the Administrative Regions in 1992. Results derived from the 1986 data and for the Postcode Areas are essentially unchanged.

The first column of Table 7 reports the baseline results for factor price equality across Administrative Regions in 1992. The baseline sample for these results includes all establishments, some of which may report on plants in more than one Administrative Region or Postcode Area. We therefore undertake the following two robustness tests. In column (2) we report coefficient estimates for the sub-sample of single plant establishments where overlap does not occur. We find a very similar pattern of results.
Second, in column (3), we allocate establishment-level data to plants on the basis of their shares of establishment employment. All plants associated with an establishment are given the same relative wages and relative wage bills. This robustness test introduces a bias against rejecting RFPE. However, even with this bias, we continue to reject RFPE with a positive and significant coefficient in the South-East and negative and significant coefficients in the Northern, Wales, and Scotland regions.

The baseline sample includes the population of establishments with more than 100 employees and a sample of establishments with fewer than 100 employees. In order to ensure that our results are not being driven by the presence of a non-random sample of smaller establishments, column (4) reports results separately for the population of establishments with more than 100 employees. Again, we find a similar pattern of results.

Our coefficient estimates are means across all four-digit industries in each region. Although each region has a large number of establishments across all industries, some individual industries within a region may contain few establishments. Since measurement error at the establishment level is a potential concern, in column (5) we drop all four-digit region-industries that contain fewer than 5 establishments. Once again RFPE is rejected and a similar pattern of estimated coefficients is observed. Finally, to ensure that the results are not driven by small region-industries with low employment levels, column (6) reports similar estimation results from a weighted regression using region-industry employment as weights.

The rejection of relative factor price equality in the U.K. is an extremely robust empirical finding. In addition, the regional pattern of rejection is stable across specifications. In the next section we explore a number of potential explanations for these results.

6. Relative Wage Differences and Industrial Structure

The Heckscher-Ohlin (HO) factor proportions framework is a special case of the production environment considered here and provides one potential explanation for our rejection of relative factor price equality. If regions have sufficiently different regional labor endowments so that regions specialize in distinct industries, and at least one type of labor displays a degree of geographical immobility, then quality-adjusted regional relative
factor prices will vary. Immobility for one type of labor prevents regional factor prices (and endowments) from converging towards a common value across the country.\footnote{See, for example, Hugues and McCormick (1994) and Jackman and Savouri (1992) for empirical evidence of limited labour mobility within the United Kingdom.}

A central prediction of the HO model is that the skill premium across regions specializing according to comparative advantage is inversely proportional to skill endowments (Leamer 1995). Our estimates of quality-adjusted relative wages in Table 3 exhibit just such a violation of factor price equality: for reasonable estimates of the elasticity of substitution between production and non-production workers, we find the skill premium to be lower in the regions around London, where skilled labor is relatively abundant, and higher in outlying areas, where skilled labor is relatively scarce.

The HO model also has an additional empirical implication: regions with different skill premia exhibit systematic differences in production structure, with skilled-abundant regions producing a set of goods that is more skilled intensive than unskilled-abundant regions. We examine this additional prediction by comparing the similarity of industry structure across regions. We run the following regression:

\[
I_{rs} = \beta_0 + \beta_1 \left| \alpha_{rs}^{NP} \right| + \beta_2 I_r + \beta_3 I_s + u_{rs} \tag{28}
\]

where \( \alpha_{rs}^{NP} \) are the estimated bilateral relative wage bill differences from equation (27), \( I_{rs} \) is the number of industries that regions \( r \) and \( s \) have in common, \( I_r \) and \( I_s \) are the number of industries produced by region \( r \) and \( s \) respectively, and \( u_{rs} \) is a stochastic error.\footnote{Up until this point, all estimates have been based solely on industries that exist in both regions \( r \) and \( s \).}

In general equilibrium, regions with fewer industries in common have larger differences in relative factor prices, corresponding to a negative and statistically significant value of \( \beta_1 \) in equation (28). Since this is a general equilibrium relationship between endogenous variables, it should be interpreted as a statistical correlation and not as a causal relationship between endogenous and exogenous variables.

Table 8 presents the results of estimating equation (28). Given the small number of bilateral comparisons available for Administrative regions,
we concentrate on Postcode Areas. As predicted by the Heckscher-Ohlin model, $\beta_1$ is negative and statistically significant in both 1986 and 1992. Larger differences in relative factor prices across regions are indeed associated with greater differences in industrial structure.\footnote{Results for Administrative Regions show a very similar pattern but, as expected given the number of Administrative Regions, are estimated with less precision.}

7. Discussion

The main findings of the previous two sections, significant variation in regional relative wages and the correlation of this factor price variation with industrial structure, are consistent with the Heckscher-Ohlin factor proportions framework. In this section, we consider alternative theoretical explanations for our results and highlight their additional empirical implications.

7.1. Region-Industry Productivity Differences, Transport Costs and Increasing Returns

Region-industry variation in total factor productivity (TFP) can also lead to a rejection of relative factor price equality. If technology is not common across regions and varies differentially across industries, relative factor prices will vary so long as workers cannot re-locate to arbitrage away wage differences. Thus, this explanation, though having a different cause than the Heckscher-Ohlin explanation, also relies upon a degree of geographical immobility in at least one factor.

To explain our empirical finding of a lower quality-adjusted skill premium in relatively skill abundant regions, it would have to be the case that technical efficiency is systematically relatively higher in low-skill intensive industries within high-skill abundant regions. An increase in technical efficiency of low-skill industries acts like an increase in the relative price of the low-skill goods, reducing the quality-adjusted skill premium, inducing a switch toward more skill intensive techniques in both sectors.

Though this explanation yields an additional empirical prediction, it seems implausible that technical efficiency is higher in skill scarce industries within skill abundant regions. If anything, considerations of knowledge
spillovers and external economies of scale appear to suggest that technical efficiency is higher in skill intensive industries disproportionately located in skill abundant regions.

A conceptually similar violation of relative factor price equality is possible via industry-region variation in transport costs. However, to match the finding of lower skill premia in skill-abundant areas, transport costs for low-skill industries must be relatively low within high-skill regions.

Geography can also play a role in a rejection of relative factor price equality via the existence of increasing returns to scale. To match the skill premia we observe, increasing returns to scale can be either internal or external, but must reduce relative (average) costs of production of low-skill industries in high-skill regions. This region variation in scale economies raises the relative demand for low-skill workers (in the skill-abundant regions) and reduces the skill premium. However, the existence of this pattern of increasing returns across industries and regions also seems implausible.

7.2. Spatial Variation in Nominal But Not Real Wages

Relative wage bills can vary systematically across regions even with perfect labor mobility. If real consumption wages are equal in each region for both types of workers, then workers have no incentive to relocate. Nominal wages may still vary due to differences in the regional cost of living associated with non-traded goods or variation in amenities. For relative wage bills to differ, the cost of living must vary differentially for skilled and unskilled workers across regions. In particular, to explain our finding of a lower relative skilled wage in the South-East, the relative cost of living must be lower there for skilled workers.

This hypothesis also involves a rejection of RFPE and implies differences in the relative cost of living for skilled and unskilled workers that are empirically testable. The hypothesis predicts the same variation in production structure as in the Heckscher-Ohlin model. Industries that are intensive in skilled workers should locate in the region with the lower nominal relative wage for skilled workers, as firms care only about their production costs and not the consumption wage of different types of workers. To fully explain our empirical findings on relative wage bill differences, the cost of living for skilled workers relative to that for unskilled workers would have to vary substantially across regions. The estimates in Table 3 sug-
gest that the cost of living for skilled workers (relative to that for unskilled workers) is fully one third lower in the South-East than in Scotland.

7.3. **Heterogeneous products**

The existence of heterogeneous products within industries can lead to a spurious rejection of RFPE. Suppose that relative factor prices are equal across all regions, but there are products with different skill requirements within each industry. If a region systematically produces products that are intensive in skilled labor (in every industry) then its relative wage bill is larger than the average for the country even if relative factor prices do not vary across regions.

Product heterogeneity can generate a false rejection of RFPE using the wage bill technique, but it has to exhibit a particular systematic pattern. This concern about the role of intra-industry heterogeneity is the reason we have exploited the highly disaggregated information on four-digit industries available in the ARD - the most detailed industry information available for our sample period. This contrasts with most existing studies which work with much coarser definitions of industries. To control for potential heterogeneity across establishments, we re-estimate the model in the robustness section for subsets of establishments with similar characteristics (e.g. single versus multi-plant or small versus large establishments). We obtain a very similar pattern of results.

7.4. **Misclassification Between Non-Production and Production Worker Categories**

One of the central features of our approach is that it controls for unobserved region-industry variation in the quality of non-production and production workers and differences in composition within these two categories of workers. However, it is susceptible to systematic errors in assigning workers between the categories of non-production and production workers. Random misclassification between categories across industry-region pairs and systematic misreporting within an industry is accounted for in our methodology. In contrast, systematic misclassification between categories across regions (e.g. all industries in region $r$ report non-production workers as production workers) can induce a spurious rejection of relative factor
price equality. While such misclassification between the categories may occur, it seems unlikely that all industries in a region will systematically misclassify workers in the same way.

8. Conclusions

We examine the extent of relative wage variation across geographic areas of the United Kingdom using a methodology that is robust to unobserved region-industry differences in factor quality and Hicks-neutral regional technology differences. We show that the empirical techniques apply under a range of assumptions about the underlying production functions and market structures. Despite the United Kingdom being a small, densely-populated country with highly integrated goods markets and the potential for factor mobility, there is strong evidence against relative wage equality across regions. There are statistically significant and quantitatively important differences in quality-adjusted relative wages across both broadly defined Administrative Regions as well as more narrowly defined Postcode Areas.

We find that skill-abundant labor markets in the South-East have a lower skill premium than skill-scarce regions for plausible values of the elasticity of substitution between skilled and unskilled workers. This variation in relative factor prices and factor quantities is precisely that predicted by the Heckscher-Ohlin model. We present additional evidence that estimated relative wage differences are systematically related to regional industrial structure in the direction predicted by the model.

We also use our framework to identify additional potential explanations for the observed variation in relative wage bills. Spatial variation in workers’ relative cost of living can provide an alternative explanation for the observed variation in skill premia and has the same implications for the variation in production structure across regions of the U.K. as the multi-cone Heckscher-Ohlin model. Other explanations based on TFP differences, increasing returns to scale, or transport costs require implausible assumptions to be made. More formal testing of these alternatives is an interesting area for further research.

Taken together, our findings suggest that variation in relative factor prices plays an important role in shaping firms’ location decisions within
the U.K.. Evidence of systematic differences in industrial structure linked to relative factor prices implies that external shocks may affect U.K. regions asymmetrically. It also relates directly to policy debates about the role of regional policies designed to attract skill intensive industries to unskilled abundant regions. The results contribute to understanding regional variation in economic outcomes within the U.K., an issue of increasing policy-interest in the context of ongoing political devolution.
References


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<td>Sheffield</td>
<td>WS</td>
<td>Walsall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN</td>
<td>Doncaster</td>
<td>SA</td>
<td>Swansea</td>
<td>WV</td>
<td>Wolverhampton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT</td>
<td>Dorchester</td>
<td>SE</td>
<td>London (South East)</td>
<td>YO</td>
<td>York</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DY</td>
<td>Dudley</td>
<td>SG</td>
<td>Stevenage</td>
<td>ZE</td>
<td>Shetland Isles (Lerwick)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Postcode Areas in the UK
<table>
<thead>
<tr>
<th>Administrative Region</th>
<th>Coeff</th>
<th>p-value</th>
<th>Administrative Region</th>
<th>Coeff</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-East</td>
<td>0.263</td>
<td>0.000</td>
<td>South-East</td>
<td>0.226</td>
<td>0.000</td>
</tr>
<tr>
<td>South-West</td>
<td>0.067</td>
<td>0.171</td>
<td>South-West</td>
<td>-0.072</td>
<td>0.123</td>
</tr>
<tr>
<td>East Anglia</td>
<td>-0.044</td>
<td>0.415</td>
<td>East Anglia</td>
<td>-0.047</td>
<td>0.343</td>
</tr>
<tr>
<td>West Midlands</td>
<td>-0.069</td>
<td>0.134</td>
<td>West Midlands</td>
<td>-0.086</td>
<td>0.048</td>
</tr>
<tr>
<td>North-West</td>
<td>-0.086</td>
<td>0.056</td>
<td>North-West</td>
<td>-0.044</td>
<td>0.290</td>
</tr>
<tr>
<td>East Midlands</td>
<td>-0.091</td>
<td>0.049</td>
<td>East Midlands</td>
<td>-0.067</td>
<td>0.121</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>-0.098</td>
<td>0.033</td>
<td>Yorkshire</td>
<td>-0.109</td>
<td>0.011</td>
</tr>
<tr>
<td>Northern</td>
<td>-0.172</td>
<td>0.001</td>
<td>Northern</td>
<td>-0.309</td>
<td>0.000</td>
</tr>
<tr>
<td>Scotland</td>
<td>-0.182</td>
<td>0.000</td>
<td>Scotland</td>
<td>-0.145</td>
<td>0.001</td>
</tr>
<tr>
<td>Wales</td>
<td>-0.187</td>
<td>0.000</td>
<td>Wales</td>
<td>-0.120</td>
<td>0.010</td>
</tr>
<tr>
<td>F-stat. (p-value)</td>
<td>0.000</td>
<td></td>
<td>F-stat. (p-value)</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>1440</td>
<td></td>
<td>Observations</td>
<td>1413</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Estimates based on pooling 4 digit industries and regions, taking the UK as a whole as the base region. p-values are heteroscedasticity robust.

Table 2: Estimation Results, Administrative Regions, UK Base
Table 3: Actual and Implied Quality-Adjusted Relative Wage Differences (CES Technology)

<table>
<thead>
<tr>
<th>Administrative Region</th>
<th>Actual</th>
<th>Quality-adjusted $\sigma = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-East</td>
<td>0.97</td>
<td>0.77</td>
</tr>
<tr>
<td>South-West</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>East Anglia</td>
<td>0.99</td>
<td>1.05</td>
</tr>
<tr>
<td>West Midlands</td>
<td>1.00</td>
<td>1.07</td>
</tr>
<tr>
<td>North-West</td>
<td>1.00</td>
<td>1.09</td>
</tr>
<tr>
<td>East Midlands</td>
<td>0.93</td>
<td>1.10</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>1.00</td>
<td>1.10</td>
</tr>
<tr>
<td>Northern</td>
<td>1.07</td>
<td>1.19</td>
</tr>
<tr>
<td>Scotland</td>
<td>1.01</td>
<td>1.20</td>
</tr>
<tr>
<td>Wales</td>
<td>1.06</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Notes: Actual relative wages are means across 4 digit industries within region relative to the UK average. Quality-adjusted wages are derived from a CES production function with an elasticity of substitution equal to 2. Coefficients used to evaluate quality-adjusted relative wage differences are from Table 2, based on pooling 4 digit industries and regions, taking the UK as a whole as the base region.
### Positive and Significant Region Coefficients at the 10% Level

<table>
<thead>
<tr>
<th>Postcode Region</th>
<th>Coeff</th>
<th>Quality-adjusted $\sigma = 2$</th>
<th>Postcode Region</th>
<th>Coeff</th>
<th>Quality-adjusted $\sigma = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sutton</td>
<td>0.559</td>
<td>0.57</td>
<td>Sutton</td>
<td>0.623</td>
<td>0.54</td>
</tr>
<tr>
<td>St Albans</td>
<td>0.364</td>
<td>0.69</td>
<td>Hemel Hempstead</td>
<td>0.311</td>
<td>0.73</td>
</tr>
<tr>
<td>Cambridge</td>
<td>0.298</td>
<td>0.74</td>
<td>Slough</td>
<td>0.303</td>
<td>0.74</td>
</tr>
<tr>
<td>Redhill</td>
<td>0.271</td>
<td>0.76</td>
<td>Swindon</td>
<td>0.283</td>
<td>0.75</td>
</tr>
<tr>
<td>Kingston</td>
<td>0.247</td>
<td>0.78</td>
<td>Guildford</td>
<td>0.208</td>
<td>0.81</td>
</tr>
<tr>
<td>Hemel Hempstead</td>
<td>0.244</td>
<td>0.78</td>
<td>Enfield</td>
<td>0.201</td>
<td>0.82</td>
</tr>
<tr>
<td>Swindon</td>
<td>0.237</td>
<td>0.79</td>
<td>Reading</td>
<td>0.187</td>
<td>0.83</td>
</tr>
<tr>
<td>Twickenham</td>
<td>0.236</td>
<td>0.79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slough</td>
<td>0.195</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>F-stat. (p-value)</strong></td>
<td>0.00</td>
<td></td>
<td><strong>F-stat. (p-value)</strong></td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>5044</td>
<td></td>
<td><strong>Observations</strong></td>
<td>5027</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Coefficients based on pooling 4 digit industries and postcode areas, taking the UK as a whole as the base region. Listed regions have statistically significant positive coefficients at the 10% level. p-values are heteroscedasticity robust. Quality-adjusted wages are derived from a CES production function with an elasticity of substitution equal to 2.

Table 4: Postcode Areas With Wage Bill Ratios Significantly Above that of the UK
### Negative and Significant Region Coefficients at the 10% Level

<table>
<thead>
<tr>
<th>Postcode Region</th>
<th>Coeff</th>
<th>Quality-adjusted (σ = 2)</th>
<th>Postcode Region</th>
<th>Coeff</th>
<th>Quality-adjusted (σ = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Llandrindod Wells</td>
<td>-0.669</td>
<td>1.95</td>
<td>Dumfries</td>
<td>-0.504</td>
<td>1.66</td>
</tr>
<tr>
<td>Dumfries</td>
<td>-0.530</td>
<td>1.70</td>
<td>Aberdeen</td>
<td>-0.433</td>
<td>1.54</td>
</tr>
<tr>
<td>Chester</td>
<td>-0.432</td>
<td>1.54</td>
<td>Cleveland</td>
<td>-0.366</td>
<td>1.44</td>
</tr>
<tr>
<td>Galashiels</td>
<td>-0.392</td>
<td>1.48</td>
<td>Sunderland</td>
<td>-0.364</td>
<td>1.44</td>
</tr>
<tr>
<td>Watford</td>
<td>-0.364</td>
<td>1.44</td>
<td>Plymouth</td>
<td>-0.330</td>
<td>1.39</td>
</tr>
<tr>
<td>Sunderland</td>
<td>-0.357</td>
<td>1.43</td>
<td>Blackpool</td>
<td>-0.327</td>
<td>1.39</td>
</tr>
<tr>
<td>Exeter</td>
<td>-0.350</td>
<td>1.42</td>
<td>Cardiff</td>
<td>-0.322</td>
<td>1.38</td>
</tr>
<tr>
<td>Llandudno</td>
<td>-0.344</td>
<td>1.41</td>
<td>Kilmarnock</td>
<td>-0.319</td>
<td>1.38</td>
</tr>
<tr>
<td>Aberdeen</td>
<td>-0.322</td>
<td>1.38</td>
<td>Truro</td>
<td>-0.306</td>
<td>1.36</td>
</tr>
<tr>
<td>Peterborough</td>
<td>-0.285</td>
<td>1.33</td>
<td>Newcastle</td>
<td>-0.296</td>
<td>1.34</td>
</tr>
<tr>
<td>Plymouth</td>
<td>-0.282</td>
<td>1.33</td>
<td>Llandudno</td>
<td>-0.293</td>
<td>1.34</td>
</tr>
<tr>
<td>Durham</td>
<td>-0.260</td>
<td>1.30</td>
<td>Canterbury</td>
<td>-0.276</td>
<td>1.32</td>
</tr>
<tr>
<td>Doncaster</td>
<td>-0.249</td>
<td>1.28</td>
<td>Darlington</td>
<td>-0.273</td>
<td>1.31</td>
</tr>
<tr>
<td>Cleveland</td>
<td>-0.239</td>
<td>1.27</td>
<td>Wolverhampton</td>
<td>-0.252</td>
<td>1.29</td>
</tr>
<tr>
<td>Sheffield</td>
<td>-0.236</td>
<td>1.27</td>
<td>Wakefield</td>
<td>-0.251</td>
<td>1.29</td>
</tr>
<tr>
<td>Kilmarnock</td>
<td>-0.234</td>
<td>1.26</td>
<td>Halifax</td>
<td>-0.245</td>
<td>1.28</td>
</tr>
<tr>
<td>Cardiff</td>
<td>-0.221</td>
<td>1.25</td>
<td>Bradford</td>
<td>-0.231</td>
<td>1.26</td>
</tr>
<tr>
<td>Crewe</td>
<td>-0.218</td>
<td>1.24</td>
<td>Bath</td>
<td>-0.220</td>
<td>1.25</td>
</tr>
<tr>
<td>Walsall</td>
<td>-0.197</td>
<td>1.22</td>
<td>Sheffield</td>
<td>-0.210</td>
<td>1.23</td>
</tr>
<tr>
<td>Dudley</td>
<td>-0.190</td>
<td>1.21</td>
<td>Wigan</td>
<td>-0.208</td>
<td>1.23</td>
</tr>
<tr>
<td>Manchester</td>
<td>-0.171</td>
<td>1.19</td>
<td>Motherwell</td>
<td>-0.207</td>
<td>1.23</td>
</tr>
<tr>
<td>Wolverhampton</td>
<td>-0.167</td>
<td>1.18</td>
<td>Oldham</td>
<td>-0.200</td>
<td>1.22</td>
</tr>
<tr>
<td>Newport</td>
<td>-0.152</td>
<td>1.16</td>
<td>Nottingham</td>
<td>-0.188</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carlisle</td>
<td>-0.185</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Walsall</td>
<td>-0.185</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hull</td>
<td>-0.181</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dudley</td>
<td>-0.174</td>
<td>1.19</td>
</tr>
</tbody>
</table>

**F-stat. (p-value)**: 0.00  
**Observations**: 5044

Notes: Coefficients are based on pooling 4 digit industries and postcode areas, taking the UK as a whole as the base region. Listed regions have statistically significant negative coefficients at the 10% level. p-values are heteroscedasticity robust. Quality-adjusted wages are derived from a CES production function with an elasticity of substitution equal to 2.

Table 5: Postcode Areas With Wage Bill Ratios Significantly Below that of the UK
## Table 6: Bilateral Region-Pair Rejections

<table>
<thead>
<tr>
<th>Region Definition</th>
<th>Fraction of All Region-Pairs Rejecting FPE</th>
<th>Distribution of Rejections Across All Base Regions at the 10% Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5% Level of Significance</td>
<td>10% Level of Significance</td>
</tr>
<tr>
<td>Administrative Regions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>0.46</td>
<td>0.57</td>
</tr>
<tr>
<td>1986</td>
<td>0.37</td>
<td>0.40</td>
</tr>
<tr>
<td>Postcode Areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>1986</td>
<td>0.12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Notes: Bilateral regressions use each region, in turn, as a base region in testing for factor price equality. These regressions analyze wage bills across 4 digit industries in 10 Administrative Regions and 111 Postcode Areas. The first two columns report the share of rejections out of the total number of possible rejections. Total possible bilateral rejections are 90 and 12,210 for Administrative Regions and Postcode Areas, respectively. The final three columns given the minimum, mean and maximum number of rejections for each base region. Total possible rejections for each base region are 9 and 110 for Administrative Regions and Postcode Areas, respectively. p-values are heteroscedasticity robust.
### Table 7: 1992 Administrative Region Coefficients For Various Specifications

<table>
<thead>
<tr>
<th>Administrative Region</th>
<th>(1) Base Results</th>
<th>(2) Single Plant Establishments</th>
<th>(3) Plant-level Estimation Results</th>
<th>(4) Establishments with &gt;100 employees</th>
<th>(5) Establishments Per Region-Industry Pair</th>
<th>(6) Base Sample, Weighted Estimation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-East</td>
<td>0.263 *</td>
<td>0.200 *</td>
<td>0.232 *</td>
<td>0.280 *</td>
<td>0.256 *</td>
<td>0.206 *</td>
</tr>
<tr>
<td>South-West</td>
<td>0.067</td>
<td>0.115 *</td>
<td>0.005</td>
<td>-0.013</td>
<td>0.015</td>
<td>0.073</td>
</tr>
<tr>
<td>East Anglia</td>
<td>-0.044</td>
<td>0.049</td>
<td>0.055</td>
<td>0.062</td>
<td>-0.053</td>
<td>0.072</td>
</tr>
<tr>
<td>West Midlands</td>
<td>-0.069</td>
<td>-0.060</td>
<td>-0.063</td>
<td>-0.120 *</td>
<td>-0.056</td>
<td>-0.029</td>
</tr>
<tr>
<td>North-West</td>
<td>-0.086</td>
<td>-0.049</td>
<td>-0.015</td>
<td>-0.076</td>
<td>-0.072</td>
<td>-0.043</td>
</tr>
<tr>
<td>East Midlands</td>
<td>-0.091 *</td>
<td>-0.043</td>
<td>-0.035</td>
<td>-0.086</td>
<td>-0.030</td>
<td>-0.041</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>-0.098 *</td>
<td>-0.059</td>
<td>-0.037</td>
<td>-0.094 *</td>
<td>-0.074</td>
<td>-0.062</td>
</tr>
<tr>
<td>Northern</td>
<td>-0.172 *</td>
<td>-0.129 *</td>
<td>-0.101 *</td>
<td>-0.214 *</td>
<td>-0.347 *</td>
<td>-0.197 *</td>
</tr>
<tr>
<td>Scotland</td>
<td>-0.182 *</td>
<td>-0.214 *</td>
<td>-0.129 *</td>
<td>-0.161 *</td>
<td>-0.151 *</td>
<td>-0.169 *</td>
</tr>
<tr>
<td>Wales</td>
<td>-0.187 *</td>
<td>-0.133 *</td>
<td>-0.103 *</td>
<td>-0.227 *</td>
<td>-0.196 *</td>
<td>-0.229 *</td>
</tr>
<tr>
<td>F-stat. (p-value)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Observations</td>
<td>1440</td>
<td>1317</td>
<td>1551</td>
<td>1309</td>
<td>593</td>
<td>1440</td>
</tr>
</tbody>
</table>

Notes: * denotes statistical significance at the 5% level. Column (1) reports results from Table 1. Column (2) reports results based upon a sample of single plant establishments. Column (3) reports results where establishment-level data are allocated to plants on the basis of their shares of establishment employment. Column (4) reports results for the population of establishments with more than 100 employees. Column (5) reports results where region-industry pairs are excluded if they have fewer than five establishments. Column (6) reports weighted estimation results using industry-region employment as weights. p-values are heteroscedasticity robust.
Factor Price Equalization in the UK?

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Coeff</th>
<th>p-value</th>
<th>Coeff</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abs Wage Bill Coeff</td>
<td>-1.208</td>
<td>0.000</td>
<td>-0.983</td>
<td>0.000</td>
</tr>
<tr>
<td>Industries in r</td>
<td>0.304</td>
<td>0.000</td>
<td>0.305</td>
<td>0.000</td>
</tr>
<tr>
<td>Industries in s</td>
<td>0.308</td>
<td>0.000</td>
<td>0.320</td>
<td>0.000</td>
</tr>
<tr>
<td>Constant</td>
<td>-11.384</td>
<td>0.000</td>
<td>-11.732</td>
<td>0.000</td>
</tr>
<tr>
<td>Obs</td>
<td>6105</td>
<td></td>
<td>6105</td>
<td></td>
</tr>
<tr>
<td>F-stat. (p-value)</td>
<td>0.000</td>
<td></td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.83</td>
<td></td>
<td>0.84</td>
<td></td>
</tr>
</tbody>
</table>

Notes: bilateral comparisons of production overlap and estimated differences in relative wage bills for 111 Postcode Areas. Dependent variable is the number of industries produced in both region r and region s. Independent variables are the absolute value of the estimated difference in relative wage bills from equation (23) ($\alpha_{rs}$); the number of industries produced in region r; and the number of industries produced in region s. p-values are heteroscedasticity robust.

Table 8: Relative Wage Differences and Industrial Structure
Figure 1: Administrative Region Estimates, 1992
Figure 2: Postcode Area Estimates, 1992