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Working Paper Series

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ECINEQ 2023 660

ECINEQ 2023 660
2023 November
www.ecineq.org

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Keyword: Redistributive effect, redistribution, horizontal inequity, reranking, Urban-Lambert decomposition, income tax

JEL Cassification: D31, H24, H50, I38

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Direct taxation in the UK, 1977–2020

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1. Introduction

Peter Lambert has had a major influence on how economists measure horizontal inequity, developing innovative methods that relate this concept to other components of the redistributive effect of income taxation. In this paper, we salute Peter's contributions by examining redistributive effect and horizontal inequity in the UK, yearly over the period 1977 to 2020, using the measurement lens Peter developed with Ivica Urban (Urban and Lambert 2008).

The essence of the horizontal equity principle is procedural fairness, typically summarized as the equal treatment of equals and a lack of unfair or capricious discrimination in taxation (Jenkins and Lambert 1999, p. 536). Few would contest this statement when expressed at this level of generality but there has been much debate about how to measure deviations from horizontal equity in practice.

Interest in measuring horizontal inequity took off in the 1980s and, increasingly, research linked inequity with the reranking of individuals between the pre- and post-tax income distributions. Oft-cited contributions include Atkinson (1980), Feldstein (1976), and Plotnick (1981, 1982). See Kaplow (1989) for a critique. Around the same time, Nanak Kakwani (1984) showed how the overall redistributive effect of the income tax system, as summarized by the difference between the Gini coefficients for pre- and post-tax income, could be decomposed into a term representing pure inequality reduction (itself depending on the average tax rate and the degree of tax progressivity) and a term representing the reranking induced by taxation (reducing redistributive effect). It was natural to label these the vertical and horizontal effects of taxation respectively, thereby helping cement the link between reranking and horizontal inequity.

Peter Lambert's research with co-authors challenged this linking and characterized horizontal inequity and reranking as separate contributions to redistributive effect:

> 'Horizontal inequity in income taxation has been identified with utility reranking by several authors, beginning with Feldstein (1976). Yet the former concept clearly refers to the (unequal) treatment of equals, and the latter to an effect among unequals. In this paper, we develop a new theoretical construction to show that the two phenomena, unequal treatment of equals and reranking among unequals, can be separately captured as distinct contributions to the redistributive impact of an income tax.' (Aronson, Johnson, and Lambert, 1994, p. 262.)

For further exposition of the Aronson, Johnson, and Lambert (1994, 'AJL') approach, see also Aronson and Lambert (1994).

The Aronson, Johnson, and Lambert (1994) article is also an important contribution because it anticipated empirical implementation issues, notably how to define pre-tax equals. On the one hand, there is the choice of appropriate equivalence scale to make pre-tax money incomes comparable in living standards terms; this is a necessary step in any horizontal inequity measurement exercise (but see Jenkins 1988 for an alternative). On the other hand, specifically relevant to the AJL approach, conditional on equivalence scale choice, there are few or no individuals with the same pre-tax income, and so empirical researchers must use a definition of 'close' equals rather than of exact equals. That is, they must choose a pre-tax income range ('bandwidth') that spans individuals considered to have the same pre-tax income. Aronson, Johnson, and Lambert (1994) checked the sensitivity of their headline estimates to bandwidth size when applying their approach to UK data for 1990/91. This checking was also an integral feature of Lambert and Ramos's (1997) approach to horizontal inequity measurement, based on the mean logarithmic deviation inequality index rather than the Gini coefficient used by AJL. For further discussion, see also Lambert (1995, especially section VI).

The new AJL decomposition approach strongly influenced subsequent empirical research. For example, Aronson, Lambert, and Trippeer (1999) applied it to 12 years of US data covering 1979–1990. Wagstaff et al. (1999) provided a cross-national comparative analysis for 12 countries around 1990. Hyun and Lim (2005) studied Korea, comparing 1991, 1996, and 2000. Kim and Lambert (2009) reported decompositions using US data for 1994, 1999, and 2004. Bandwidth choice was the focus of van de Ven, Creedy, and Lambert's (2001) research using Australian data for 1995/96, including a proposal that the bandwidth be chosen to maximize the vertical component of redistributive effect.

Urban and Lambert (2008) developed the AJL framework further in important ways to address issues arising when close equals groups (CEGs) are used. Their motivating insight was the recognition that the AJL framework did not properly consider the phenomena of reranking within CEGs (separately from overall reranking) or the possibility that entire CEGs may be reranked by income taxation. Building on this, Urban and Lambert provide a new framework for decomposing redistributive effect into vertical, horizontal, and reranking components that distinguishes three distinct forms of reranking. Also, notably, when summarizing horizontal inequity, the UL approach builds connections with that employed by King (1983) and Jenkins (1994) because it summarizes differences between individuals' actual post-tax incomes and the post-tax incomes they would have were there to be no horizontal inequity within each person's CEG. This is the situation arising if all members of a CEG face a common tax rate equal to the ratio of tax paid to total pre-tax income for their CEG. This 'smoothing' counterfactual differs from the within-CEG average counterfactual used by the AJL approach.

Urban and Lambert's (2008) empirical application is to Croatian data for 1997, 2001, and 2003, and includes careful examination of the robustness of estimates to the choice of bandwidth. As far as we are aware, there have been only two other applications of the UL approach. One is by Hérault and Azpitarte (2014) to ten years of data for Australia covering 1994 to 2009. The other is by Nolan (2018) using New Zealand data for 1988–91 and 2011–13 (data for three years pooled in each case).

Against this background, the current paper makes several contributions. We derive the first estimates for the UK of the UL decomposition of redistributive effect into vertical, horizontal, and reranking components. Our estimates cover the 44 years between 1977 and 2020, and so provide a more fine-grained and up-to-date analysis of trends in decomposition components than do earlier studies in the AJL and UL tradition. We also address bandwidth choice issues anew, including a novel variant in which bandwidth is defined in terms of quantile group membership rather than income value. The motivation is that using a fixed real-income bandwidth across years (or countries) is not necessarily appropriate when there are large differences in pre-tax income distribution over time (or place).

We find that redistributive effect increased over the period. However, there is no clear trend in horizontal inequity and this component forms a very small fraction of total redistributive effect by comparison with reranking and especially vertical components. It is also the vertical component that best tracks trends in redistributive effect. Our in-depth analysis of the effects of choosing different bandwidths reveals that implausible estimates of the horizontal inequity component arise for some years regardless of bandwidth used but more particularly so for large bandwidths.

In Section 2, we provide more details of the UL approach to decomposing redistributive effect and contrast it with the AJL and Kakwani approaches. Section 3 discusses our data set and Section 4 presents our estimates and compares them with those from earlier studies. Section 5 contains a summary and conclusions.

2. The Urban-Lambert and other approaches to decomposing redistributive effect

We use the same notation as Urban and Lambert (2008). Let X refer to the distribution of pre-tax income and N to the distribution of post-tax income in a population of individuals. We assume that all incomes have been adjusted using a suitable equivalence scale.

The redistributive effect of income tax (RE) is the difference between the pre- and post-tax Gini coefficients, G_X and G_N:

$$RE = G_X - G_N. \tag{1}$$

2.1 Decompositions of redistributive effect

Kakwani (1984) showed that RE can be decomposed into two terms:

$$RE = V^K - R^{APK}. \tag{2}$$

The first term, vertical redistribution, $V^K = [t/(1-t)]P^K$, has two components. The first depends on t, the average tax rate, equal to total amount of taxes paid expressed as a fraction of total pre-tax income in the population. The second component, P^K, is the Kakwani index of tax progressivity, which equals zero in the case when everyone's tax payment is the same (common) proportion of their pre-tax income and is larger the greater the deviation from proportionality (when taxes are more progressive).

The second term in the decomposition, R^{APK}, summarizes the extent of reranking of individuals between the pre- and post-tax income distributions, and is equal to the difference between the Gini coefficient for post-tax incomes and the concentration coefficient for post-tax incomes ranked by pre-tax income. The 'AP' in the 'APK' tag arises because Atkinson (1980) and Plotnick (1981) proposed R^{APK} as a measure of horizontal component of redistributive effect.

Aronson, Johnson, and Lambert's (1994) decomposition of redistributive effect can be written as:

$$RE = V^{AJL} - H^{AJL} - R^{AJL}. \tag{3}$$

Neatly, this decomposition includes a term which encapsulates classical horizontal inequity in the sense of summarizing the differences in post-tax income among individuals with the same pre-tax income: H^{AJL} is a weighted average of the post-tax income Gini coefficients for the groups of pre-tax equals. Horizontal inequity reduces redistributive effect (witness the negative sign). So too does reranking, summarized by R^{AJL}.

A key insight of Urban and Lambert (2008) was that R^{AJL} does not incorporate all potential types of reranking. Specifically, it omits reranking within each CEG (summarized by a factor R^{WG}) and the reranking of entire CEGs (summarized by a factor R^{EG}). That is,

$$R^{AJL} = R^{APK} - R^{WG} - R^{EG}. \tag{4}$$

Urban and Lambert (2008) proposed a new decomposition of redistributive effect:

$$RE = V - H - R. \tag{5}$$

They show that entire-CEG reranking is now treated as a vertical redistribution component:

$$V = V^{AJL} + R^{EG}. \tag{6}$$

In addition,

$$H = H^{AJL} - R^{WG}, \tag{7}$$

i.e., the horizontal effect of taxation is now purely about the extent to which (close) equals are treated differently and within-CEG reranking is netted out. Observe that if all individuals can be classified into groups with exactly equal pre-tax incomes (rather than having to use CEGs), $R^{WG} = 0$ and, moreover, if taxation does not re-rank entire pre-tax groups, $R^{EG} = 0$. In this case, the UL decomposition reduces to the AJL one.

From (4) – (7), $R = R^{APK}$. This implies that $V^{APK} = V - H$, highlighting that Kakwani's decomposition does not identify the pure horizontal effect of taxation. Note also that the sizes of RE and R do not depend on the choice of bandwidth.

2.2 Bandwidth choice issues

Bandwidth choice affects how much of V^{APK} is attributed to V and how much is offset by horizontal inequity H. For a careful discussion of the effects of changing bandwidth, see van de Ven, Creedy, and Lambert (2001) who refer to 'averaging' and 'accumulation' effects. But their analysis refers to the AJL decomposition, not the UL one, as Urban and Lambert point out (2008, p. 580). Nevertheless, one might expect the estimate of H to first rise as the bandwidth is increased from zero but then to fall. If the bandwidth is near zero, H will tend to zero because there are very few equals to compare. As the bandwidth increases, there are more equals, and H will increase. However, when the bandwidth gets very large, CEGs include more and more individuals with very different pre-tax incomes, and within-CEG reranking rises and this will pull H downwards in addition to any effects on H^{AJL} (see (7)). This story is complicated by the fact that changing the bandwidth also changes the counterfactual (smoothed) tax system (Urban and Lambert, p. 577). Moreover, the threshold bandwidth at which H (or V) reaches a maximum is dependent on temporal (or country) context. In any case, it is clear that H may have negative values with sufficiently large bandwidths. Negative values are inconsistent with an interpretation of H in terms of post-tax income dispersion among pre-tax equals because dispersion cannot be negative.

We conclude that researchers should use bandwidths that avoid these incongruous estimates. Urban and Lambert do not state this recommendation explicitly but their remarks are consistent with it. For example, commenting on their Croatian estimates, they write "[f]or very large bandwidths, as figure 2 shows, H is seriously *under-estimated*, becoming large and negative" (Urban and Lambert, 2008, p. 580, emphasis added). Their motivation for and development of a 'total' horizontal measure (H^T) is also consistent with the rule of thumb we propose: see section 2.3 below for details and also note that H^T is guaranteed to be non-negative. More generally, we conclude that the appropriate empirical strategy is to follow Urban and Lambert's recommendation to 'produce plots that show the dependencies of the various contributions on the bandwidth selected' (2008, p. 584) and to focus on the decomposition and H^T estimates for bandwidths yielding non-negative estimates for H.

Bandwidth choice is further complicated if researchers derive estimates of H and V for time periods (or countries) with quite different distributional shapes. For example, in our empirical application (section 4), the Gini coefficient for pre-tax income increased substantially over the period we consider (1977–2020), from 0.275 in 1977 to 0.388 in 2020 reaching a period maximum of 0.427 in 2007. (The post-tax Gini coefficient increased from 0.253 to 0.337 over the same period, reaching 0.382 in 2007. See Figure 1 below.) The marked rise in inequality was coupled with a 101% rise in average pre-tax income (mean pre-tax income (in 2020 prices) increased from £16,531 in 1977 to £33,199 in 2020) implies that a bandwidth fixed in real income terms that is appropriate for the beginning of the period is unlikely to be appropriate for the end of the period. When inequality is low, a £100 band (say) may include many individuals across the middle-income ranges but very few in the very highest ranges, but when inequality (and average real income) is significantly higher, fewer individuals will be included in each band in the middle-income ranges and more individuals in bands in the top income ranges. (The total number of CEGs will increase as well because the distribution range increases.) The consequence is that not only does the choice of a specific fixed bandwidth affect estimates of H (and V) in any given cross-section (see above), but it also affects estimates of their changes over time (or across countries).

Observe that there is nothing in the theory underlying the decomposition of redistributive effect that requires the bandwidths defining CEGs to be the same real income value across temporal (or country) contexts. This has simply been the de facto practice in virtually all studies to date and undiscussed.

Nolan (2018) recognizes that the density of households across income bands varies substantially across the income range when a fixed bandwidth is used. As a result, he also considers income bands defined in terms of a specific (common) difference in the logarithm of income. This strategy does not deal with the cross-time comparability issue if inequality and mean income change a lot (because the log-income distribution also changes), though it may moderate the problem.

Our response to the issue is different. For one of our bandwidth choice variants, we define CEGs in terms of percentile groups of pre-tax income where the percentile groups are specific to each year. This strategy ensures that every CEG defined for a given year's distribution contains the same fraction of observations and, also, by construction, the number of groups is the same when comparing a pair of distributions for different years. Clearly, this CEG definition means that bandwidths vary in real income terms across the distribution. But this is not necessarily a problem. As Nolan puts it, '[i]ntuitively, a larger income band for defining equals for larger incomes makes sense – eg a $10,000 gap is a lot less relevant to the difference between two millionaires than it is between two beneficiaries' (2018, p. 16). The use of quantile groups allows for the bandwidths to effectively adjust to the changing shape of the income distribution, removing arbitrary variations in the number of CEGs. However, there is no strong reason to choose percentile groups over other quantile groups. Thus, we also report estimates based on half-percentile groups.

We do not claim that quantile group CEG definitions solve the cross-distribution comparability issue. Rather, we think they are worth adding to the portfolio of definitions used when checking the sensitivity of calculations.

2.3 The Urban-Lambert measure of 'total' horizontal inequity

All the decomposition components cited so far are differences between a pair of Gini coefficients or concentration coefficients for suitably-ordered distributions: see Urban and Lambert (2008, Table 3). In particular, the calculation of H is based on the difference between two concentration curves, one based on individuals ordered by pre-tax income (and among exact pre-tax equals by post-tax income), and the other based on individuals ordered by pre-tax income within groups and the groups by average post-tax income. Urban and Lambert point out that very small estimates of H may arise simply because these concentration curves cross multiple times with positive and negative differences (areas) between the curves offsetting each other. Consequently, they appeal to the 'original rationale for H (in terms of person-by-person distances between post-tax incomes and reference values)' (Urban and Lambert 2008, p. 580), and propose an additional measure of horizontal inequity.

Urban and Lambert write H as the sum of two components, one representing all areas where the effect is positive (H^P) plus a second representing all areas in where the effect is negative (H^N), and then define a new 'total' measure H^T as

$$H^T = H^P + \text{abs}(H^N) = H^P - H^N. \tag{8}$$

This 'measures total horizontal inequity across members of equals groups in terms of *absolute* deviations of post-tax incomes from the counterfactual ones, which of course cannot cancel out' (Urban and Lambert 2008, pp. 580–581, emphasis in original).

In what follows, we decompose redistributive effect in UK income taxation, year by year, using the UL decomposition approach summarized by eqn. (5) and multiple bandwidths to define CEGs. In addition to estimates of RE, V, and H, we provide estimates of the other reranking components (R^{APL}, R^{WG}, and R^{EG}) and H^T.

For calculations, we use the *sgini* module for Stata by Van Kerm (2020) and, to derive H^T, the *glcurve* module by Jenkins and Van Kerm (2008). We derived bootstrap standard errors for estimates using Van Kerm's (2013) *rhsbsample* Stata module for repeated half-sample bootstrap sampling with 500 replications. We summarise levels and trends in estimates using charts, but Appendix Table 1 reports estimates in numerical form. For brevity and legibility, we do not report confidence intervals, albeit with one important exception discussed in section 4 (Figure 7).

3. The ONS's ETB data and income concepts

Our analysis is based on the historical series of unit-record data deposited by the Office for National Statistics (ONS) at the UK Data Service (ONS 2022). We use the same data as for our Kakwani decomposition analysis in Hérault and Jenkins (2022) – plus two additional years – and the rest of this section draws on our earlier exposition.

The income variables are the same as those used by the ONS in their annual articles about the 'Effects of taxes and benefits on household incomes' ('ETB'): see, e.g., ONS (2019). The ONS derive the variables from the Living Costs and Food Survey (LCFS, from 2008) and its predecessor, the Family Expenditure Survey (FES, to 2007). The LCFS and FES are household surveys with a focus on household spending and income, each intended to be nationally representative of the UK private household population, and an annual sample size of approximately 5,000 households. Survey years refer to financial years (12-month periods starting 5 April each year) from 1993/94 onwards and to calendar years before that. For brevity we label financial years by the first part: '2016' refers to financial year 2016/17, etc. The FES and LCFS include sample weights from 1997 onwards and we use these to derive all estimates.

We follow the ONS in our definitions of the pre- and post-tax household incomes. That is, *pre-tax income*, commonly known as 'gross' income, includes total income from the labour market (from employment and self-employment), income from rents, interest and dividends, plus income from the government (cash benefits and credits). *Post-tax income*, commonly known as 'net' or 'disposable' income, is gross income minus personal income tax payments, employee national insurance contributions, and local taxes (such as council tax). The definitions of gross and disposable income correspond closely to those set out by the Canberra Group's (2011) guidelines. As in all the leading UK household surveys, the survey questions refer to 'current' incomes for almost all components. Income variables refer to responses to questions about the last income amount received and the period to which it refers is used to derive annual amounts (£ per year) pro rata.

The unit of analysis is the individual throughout: we employ the conventional assumption that each individual receives the income of the household to which s/he belongs. We adjust all household incomes and income components for differences in household size and composition using the modified-OECD equivalence scale. The ONS uses the same scale but our calculation of it differs slightly from theirs. This is because the modified-OECD scale defines children to be individuals aged 14 or under. We cannot identify children thus in the dataset we have. We only know whether an individual is a 'dependent child', i.e., aged 15 or less, or aged 16–19 and in full-time education. Thus, our equivalence scale calculations count slightly more children than the ONS do, but we expect the effects to be negligible. In addition, the ONS rescales the modified-OECD scale to use two-adult households instead of one-adult households as the reference household type with scale rate equal to 1.

The income variables are defined in the same way over the whole of the period we are considering (1977–2020), with one exception, i.e., the ONS recently incorporated an adjustment in the ETB data to address issues of under-coverage at the top of the income distribution. The ONS now replaces a very small fraction of the very highest survey incomes with individual pre-tax incomes derived from personal income administrative data (and then recalculates total household income), combining this with an adjustment to the survey weights (see ONS 2020). They have implemented the top-income adjustment retrospectively and it is included in our ETB unit-record data for all years from 2001 onwards. We believe that the impact of the top-income adjustment on the time series consistency is largely negligible, with one small exception that we mention in the next section.

We drop observations with income values equal to or less than zero. The number affected is tiny: 287 for pre-tax income and 979 for post-tax income out of 331,335 total observations (0.09% and 0.29% respectively) for the 44 years of data. All incomes and income-related bandwidths, for all years, are in units of pounds per year expressed in constant 2020 prices (derived using the Retail Price Index series MM23).

4. Empirical analysis

Figure 1 shows the raw material for our decomposition analysis. At the top of the chart are the pre- and post-tax Gini coefficients for each year over the period 1977–2020. The beginning of the period was when UK income inequality was at its lowest since 1961 (Bourquin, Brewer, and Wernham 2022, Figure 1). However, inequality increased substantially during the 1980s, and continued to increase thereafter albeit at a slower rate until the onset of the Great Recession. It then fell back so that, by the end of the period, inequality was at much the same level as at the start of the 1990s.

<Figure 1 near here>

Although this broad description describes the evolution of both pre- and post-tax income inequality, there are differences of detail in the two series. These are reflected in the series for redistributive effect, *RE*, which shows the difference between the pre- and post-tax Gini coefficients measured in 'Gini points' (differences in Gini coefficients multiplied by 100; right-hand axis). *RE* fluctuates around a relatively flat trend (between two and three Gini points) from the end of the 1970s until the early 1990s, but then increases to reach around five Gini points by the end of the Great Recession, though with substantial variation in between. *RE* remained at much the same level thereafter. Although three subperiods can be distinguished for trends in both *RE* and inequality, the directions of change in the *RE* series do not correspond to those in the inequality series. Note, however, that the marked increase in *RE* (by 1.5 Gini points) in 2001 coincides with the introduction of the top income adjustments.

The bottom series in Figure 1 is for reranking, also measured in Gini points (right-hand axis). The immediate impression is that there is little trend in *R* if one discounts the marked decline between 1977 and 1978 (which we cannot explain). Over the 1980s there is a barely perceptible decrease in *R* and then little change from around the start of the 1990s to the end of the period. Put differently, R decreased from around 17% of RE at the end of the 1970s to reach around 10% of RE in 2000 but was around 6% of RE thereafter. (We provide more discussion of the estimates for R below when discussing the decomposition of RE.)

Estimates of RE and R are not contingent on bandwidth choice but estimates of V, H (and R^{APL}, R^{WG}, R^{EG}, H^{T}) are. Our initial bandwidth sensitivity investigations involved plots of V and H against bandwidth.

First, we searched for the fixed (common) income bandwidth yielding the maximum estimate of V for each year. This exercise is in the spirit of van de Ven, Creedy, and Lambert (2001) who argue that researchers using the AJL decomposition should focus on the set of estimates corresponding to the V^{AJL}-maximizing bandwidth. (They call this the 'optimal' bandwidth though the logic for this label is not entirely clear.) Our results are striking. For 22 of the 44 years, the V-maximizing bandwidth was £50 or below, and for six of those years it was £10 (the smallest value used in our search). These are all small bandwidths: average pre-tax income in 2020 prices ranged between £16,531 in 1977 to £33,199 in 2020. These bandwidths lead to the yearly number of CEGs ranging from 43 to 6,095 with an average of 1,203 per year over the 44-year period. In practice, however, studies using the V-maximizing bandwidth over several years have derived the bandwidth for the latest year of data and applied that same value in real income terms to earlier years. See, e.g., Kim and Lambert (2009, p. 10) and Hérault and Azpitarte (2014, p. 8). In our case, this would lead to the use of the £10 bandwidth.

Second, we derived plots for each year similar to those reported by Urban and Lambert (2008, Figure 2) for Croatia in 2003, and these revealed patterns similar to theirs. That is, the plots of V and H against bandwidth are relatively flat for a relatively large range before reaching a threshold after which V and H declined quickly as bandwidth increases further. Figure 2 illustrates these results for three years: 1980, 1990 and 2020. For H in 2020, the slope is negative, and it is thus the smallest bandwidth, £10, that maximizes H. But the slope is relatively flat for all bandwidths up until £100 per year and thereafter H hovers around zero, turning negative at £400. The estimates of H are very close to zero at relatively small bandwidths, but they take larger and larger negative values as the bandwidth takes on large values. Results for 1980 and 2020 differ to some extent because H initially increases, though only slightly, as the bandwidth increases from small values. Recall, though, that V (and RE) was much larger in 2020 than in 1980 or 2000. It is only for bandwidths above £1,000 for 1980 and £5,000 for 2000 that H starts to quickly decrease and turn negative.

Overall, the patterns shown in Figure 2 warn us that large bandwidths may provide implausible results.

<Figure 2 near here>

We pursue this hypothesis further in Figure 3. This shows yearly estimates of H for a wide range of fixed bandwidths as well as the percentile and half-percentile group variants.

The £10, £100, and £1,000 fixed bandwidth variants yield estimates that are similar, except in the final decade of the period when the £1,000 variant series diverges from the other two, falling below them. The percentile-group variant series also tracks these three fixed bandwidth series, again except for the final decade, which is when percentile income bands correspond to larger and larger bandwidths in real income terms. The half-percentile group variant series is remarkably similar to the percentile-group variant series and only leads to some limited differences in the final two decades. None of the bandwidths we consider leads to a positive H value for 1987 and 1988 and H is negative from 1984 to 1990 with the £10 bandwidth. Strikingly, when the fixed bandwidth is very large (£10,000), the series for H lies below those for all the other fixed bandwidth variants. Indeed, H is negative for almost all years for this case, again suggesting that large bandwidths lead to implausible estimates.

<Figure 3 near here>

Negative estimates of total horizontal inequity H^T are impossible by construction: see section 3. We plot estimates of H^T in Figure 4 for the same set of bandwidths. There is now greater congruence in estimates across the series, but it remains the case that the series based on very large bandwidths – fixed at £10,000 throughout the period, or the percentile group variant in the final decade – diverge from the other series with smaller bandwidths, as in Figure 3. However, regardless of variant, there is no clear trend in either H or H^T: both fluctuate over time. We consider below whether there is a trend in H when expressed as a percentage of total redistributive effect.

<Figure 4 near here>

Following Urban and Lambert (2008, Figure 3), Figure 5 decomposes total reranking (R) into its three components: AJL-reranking (R^{AJL}), entire-CEG reranking (R^{EG}), and within-CEG reranking (R^{WG}). We use the same bandwidth variants as before. For the two smallest fixed bandwidth series (panels a and b), within-CEG reranking is negligible. With the smallest bandwidth of £10 entire-CEG reranking and AJL-reranking are of similar size, whereas with the £100 bandwidth AJL-reranking largely dominates all other forms of reranking. There is no obvious explanation for the abrupt regime change in R^{AJL} and R^{EG} in 2017 that are observed with the £10 bandwidth only. As the fixed bandwidth is increased to large (£1,000) and very large (£10,000) values, R^{AJL} becomes notably smaller as a fraction of R, while within-group reranking increases dramatically and becomes the largest component in the £10,000 bandwidth series. The half-percentile and the percentile group series look most like the £100 fixed bandwidth series in that about 90% of R is accounted for by AJL-reranking. However, one notable difference from the fixed bandwidth series is that the half-percentile and the percentile group series show much smoother profiles, possibly because, unlike with the fixed bandwidths, there is no variation in the number of CEGs in different years.

<Figure 5 near here>

This completes our discussion of estimate sensitivity to bandwidth choice. Our investigations have shown that very large bandwidths provide implausible estimates, including negative values for H and very large magnitudes for within-CEG group reranking. Hence, for our summary decomposition of RE into its components, we report estimates only for the two smallest fixed bandwidth variants. First we discuss the estimates and then we return again to consider bandwidth issues in relation to H.

Figure 6 shows the vertical, horizontal, and reranking effects, year by year, each expressed as a percentage of total redistributive effect to make them comparable. No major trends in the decomposition components stand out. Excluding the 1977 outlier, there is a slight decline in V and R in the first 2 decades and relative stability thereafter. V is around 120% of RE in the late 1970s and early 1980s but then essentially hovers around 110%. R is between 10% and 20% of RE until the mid-1990s but is thereafter between 5% and 10%. H fluctuates over time, reaching a peak of 4.4% of RE in 1999 but otherwise mostly remains less than 3% and is occasionally negative (a point to which we return).

How do the estimates compare with those from earlier studies using the UL approach? Hérault and Azpitarte (2014, Table 2) show V as consistently 102%–103% of RE, R about 2% (though fluctuating around that value). They report negative values for H for a couple of years, an issue we return to below. Nolan (2018, Table 4) shows V as 107% of RE for both 1988–91 and 2011–13, and H as 0% and 0.02% respectively. Hence R is around 7% for both years. Urban and Lambert (2008) report that, for 2003, H is 0.02% of RE, and from their Figures 1 and 2, we can deduce that V is about 0.068 and hence around 113% of RE. The pre-2000 UK estimates for R as a percentage of RE are of roughly the same magnitude as the fraction reported by Urban and Lambert (2008, p. 583) for Croatia in 2003, i.e., 13.6%. In sum, our estimates for the UK of V, H, and R (expressed as a % of RE) for years up until the late 1990s are thus a magnitude larger than other available estimates. In the last two decades, the UK estimates align more closely with the estimates reported by Nolan (2018) and Urban and Lambert (2008), though our estimates for *H* (as a percentage of *RE*) are generally larger than theirs.

<Figure 6 near here>

This discussion of UK levels and trends and comparisons with estimates for other countries has glossed over the fact that estimates of *H* are negative during the mid- to late-1980s for both bandwidths. (For the £100 bandwidth, there are also a few other negative values in later years.) Earlier in the paper we argued that negative *H* values were implausible, which suggests that the decomposition estimates for the problematic years should be discarded. However, apart from these slightly negative values, the estimates for these years do not stand out and so arguably this conclusion is premature. Moreover, one might argue that negative values represent the outcomes of sampling variability and hence that, if the confidence intervals for the estimates from the problematic years include zero, we should consider the estimates as insignificantly different from zero and retain them.

Figure 7 shows the 95% confidence intervals around the yearly estimates for *H* expressed as a percentage of *H* (as in Figure 6) for each of the two bandwidths. For the £10 bandwidth, there are years in the late-1980s for which the upper bounds of confidence interval are less than zero. However, with the £100 bandwidth, the 95% confidence intervals for *H* (as % of *RE*) include zero for all the years for which the point estimate is negative. We conclude that we prefer the decomposition series based on the £100 bandwidth rather than the £10 bandwidth – though we are also reassured that this preference has little material effect. The series shown in the two panels of Figure 6 are generally very similar in terms of levels and trends.

<Figure 7 near here>

5. Summary and conclusions

Urban and Lambert (2008) provide a new approach to the decomposition of redistributive effect of taxation into vertical, horizontal, and reranking components that modifies the early Aronson, Johnson, and Lambert (1994) approach to properly incorporate reranking within and across entire CEGs. The UL approach does not solve the problem of how CEGs should be defined: researchers still need to check the sensitivity of their decomposition estimates to the choice of bandwidth.

In this first UL-approach application to the UK, one covering 44 years, we find that total redistributive effect in any given year is mostly due to the vertical effect, with the reranking effect between 5 to 20 percent of the total and the horizontal effect near zero. This finding chimes with the three previous UL studies (to Croatia, Australia, and New Zealand). But our long run of data also enables us to provide a more fine-grained and up-to-date analysis of trends in decomposition components than do earlier studies. We find that the substantial increase in redistributive effect between 1977 and 2020 is tracked by a parallel increase in the vertical component. By contrast, there are no systematic trends in the horizontal and reranking components.

We have highlighted bandwidth issues, pointing out that choices are complicated further when researchers undertake and compare redistributive effect decompositions for income distributions that differ a lot in shape. We have explored the use of an alternative to the fixed bandwidths used in previous studies by using bandwidths based on percentile and half-percentile groups, noting that they have the advantage of not imposing arbitrary variations in the number of CEGs across years. We have illustrated the issues with yearly data covering a period over which income inequality increased substantially, showing that only small bandwidths provide estimates that are plausible, i.e., guaranteeing that the horizontal component is non-negative in (almost) all years. We have also shown how examination of whether the confidence intervals for H span zero adds additional information relevant to the final choice of bandwidth.

The final sentence of Jenkins and Lambert's (1999) survey article was 'the current situation could well be described, *pace* Kaplow (1989), as "horizontal equity: principles in search of a measure"' (1999, p. 551). More than two decades later, there are now well-defined measures: Peter Lambert's careful research on horizontal inequity led to important clarifications and developments. However, it is perhaps ironic that the empirical applications of those measurement systems have found that horizontal inequity is a negligible fraction of redistributive effect (vertical and reranking components are much more important). This raises questions about the nature of future research on horizontal inequity.

Acknowledgements

Paper prepared for a special issue of the *Journal of Income Distribution* in honour of Peter Lambert (guest editors: John Creedy and Sreenivasan Subramanian). Peter: salutamus vos! We thank Ivica Urban for his helpful responses to our queries and comments. Nicolas Hérault acknowledges financial support from the French Ministry of Higher Education and Research and the French National Research Agency.

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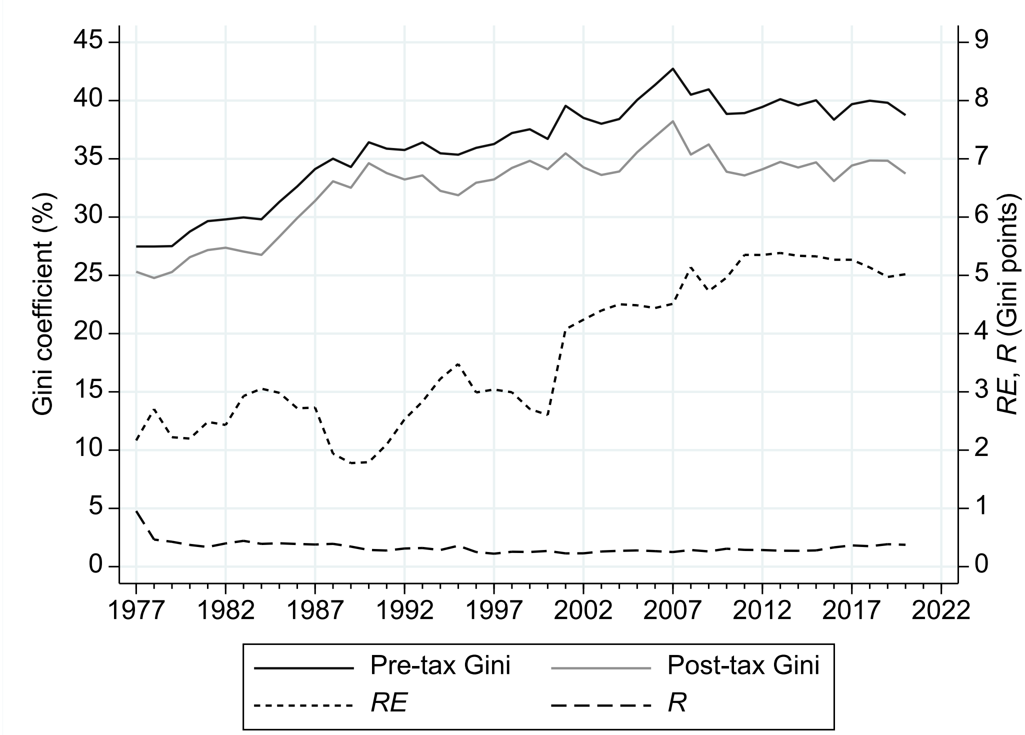
Figure 1. Gini coefficients (%) for pre- and post-tax income, redistributive effect (*RE*), and reranking (*R*), UK, 1977–2020



Notes: Income definitions are explained in Section 3.

Figure 2. ***V*** **and** ***H*** **plotted over a large range of bandwidths, UK, 1980, 2000, and 2020**

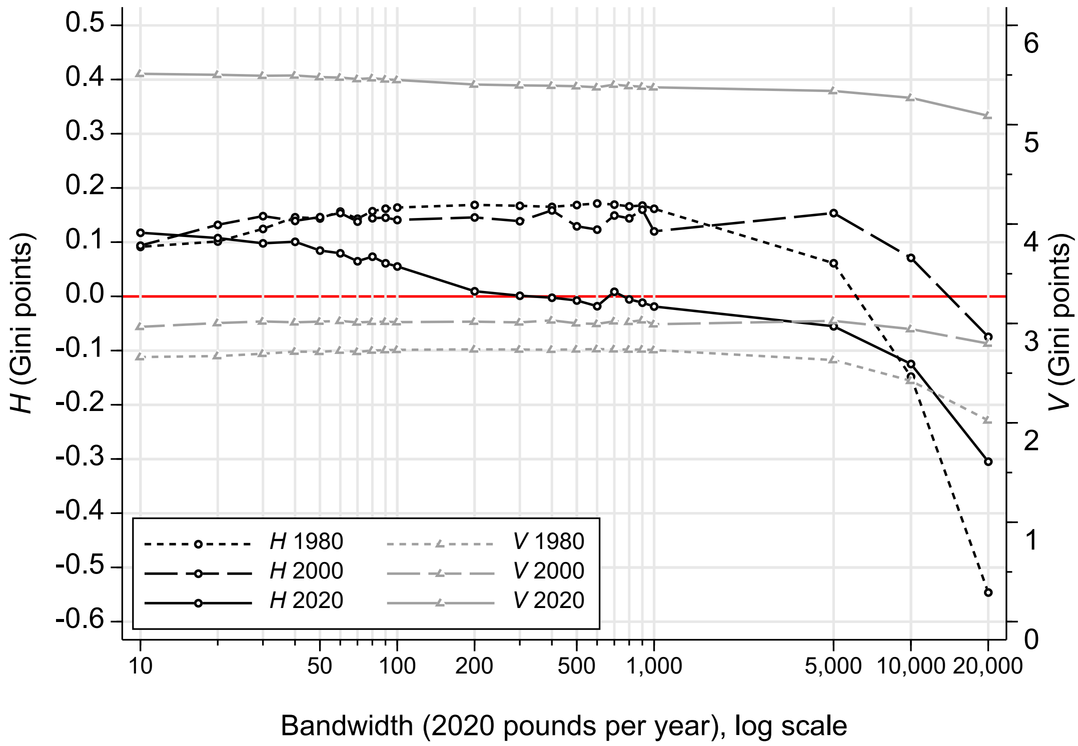
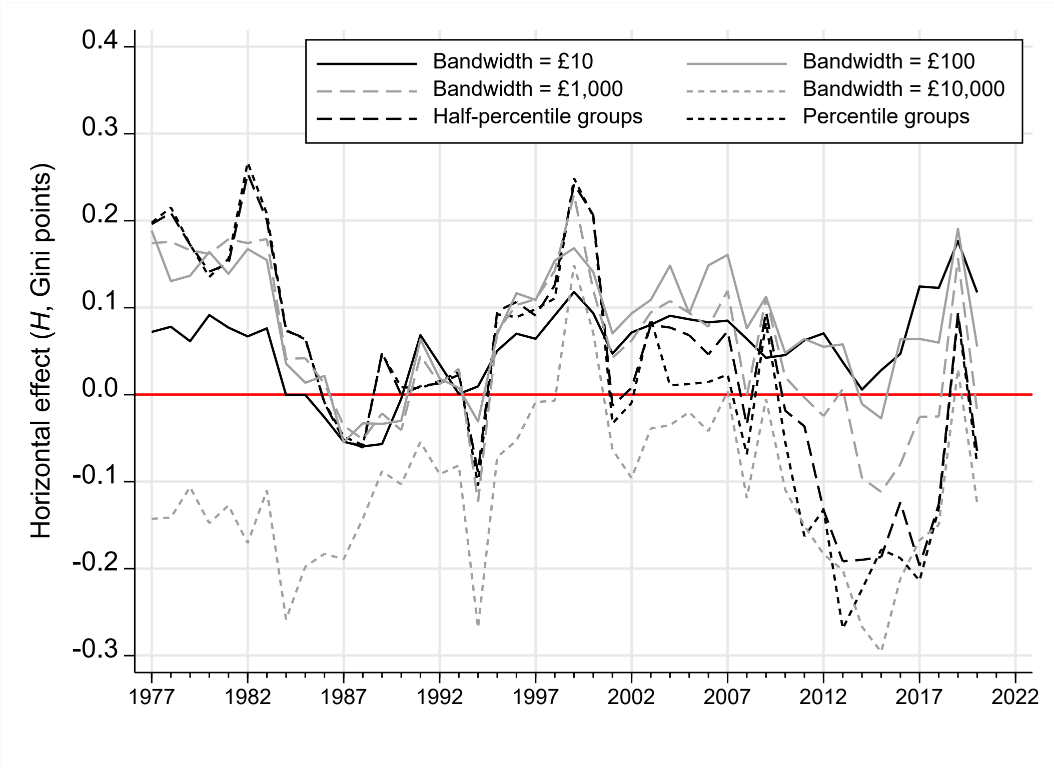
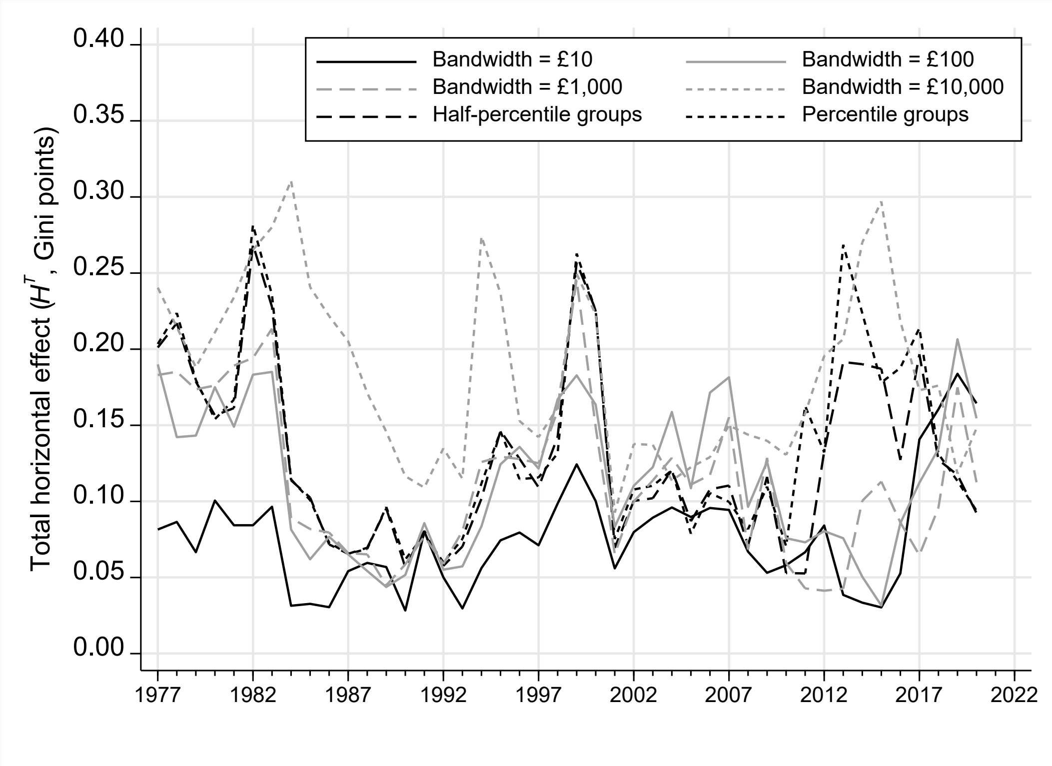


Figure 3. ***H*** **by bandwidth and year, UK, 1977–2020**



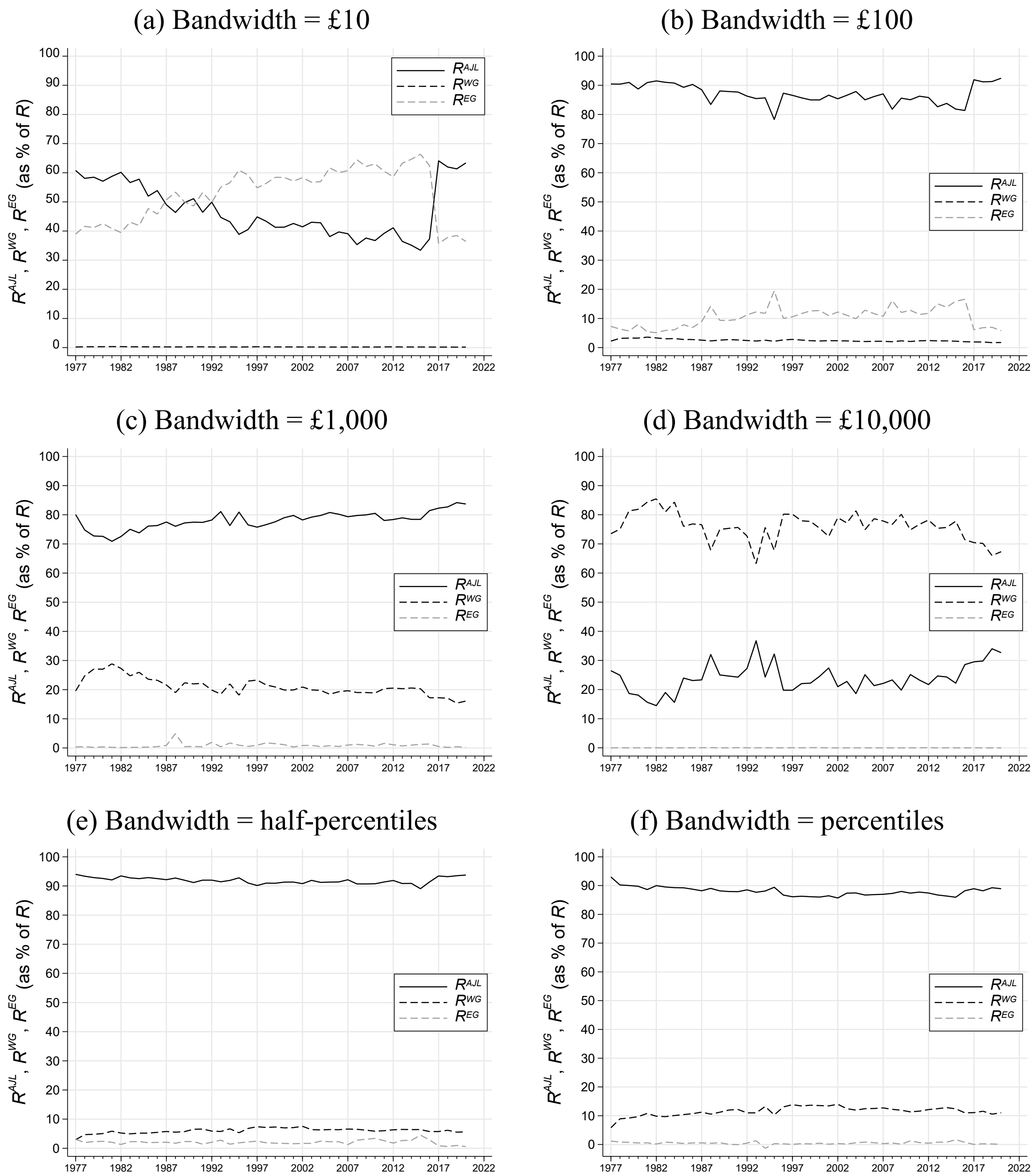
Notes: Bandwidths in pounds are expressed in constant 2020 prices.

Figure 4. Total horizontal inequity (H^T) by bandwidth and year, UK, 1977–2020



Notes: Bandwidths in pounds are expressed in constant 2020 prices.

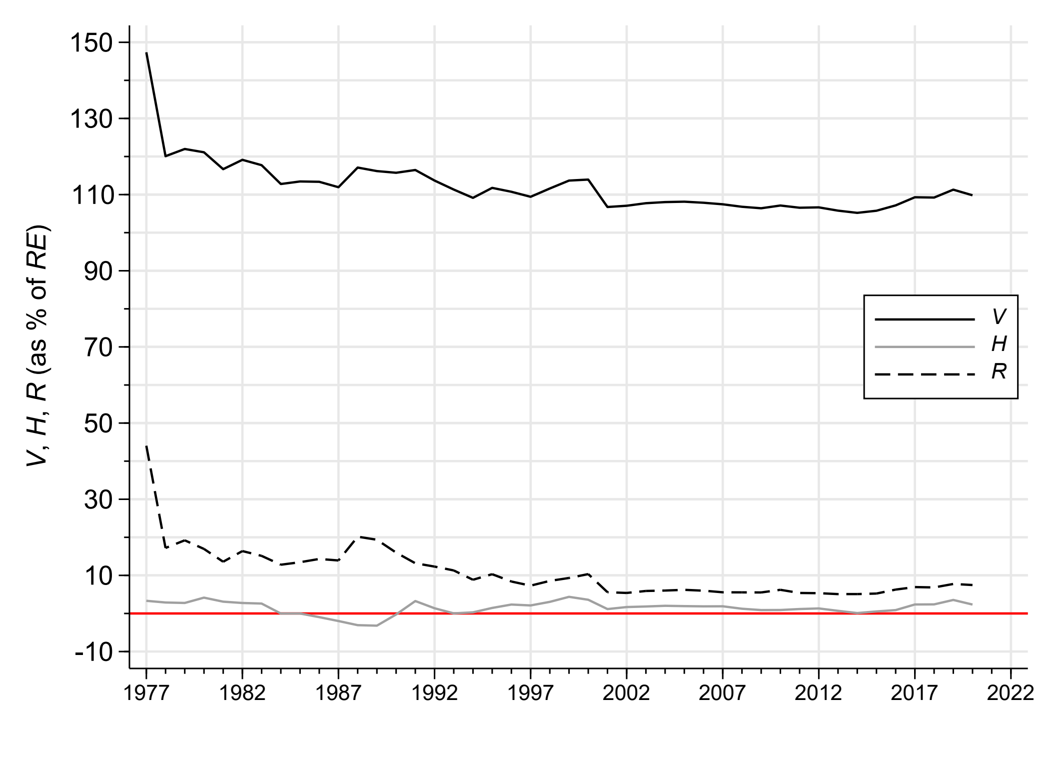
Figure 5. Reranking (*R*) decomposition by bandwidth and year, UK, 1977–2020



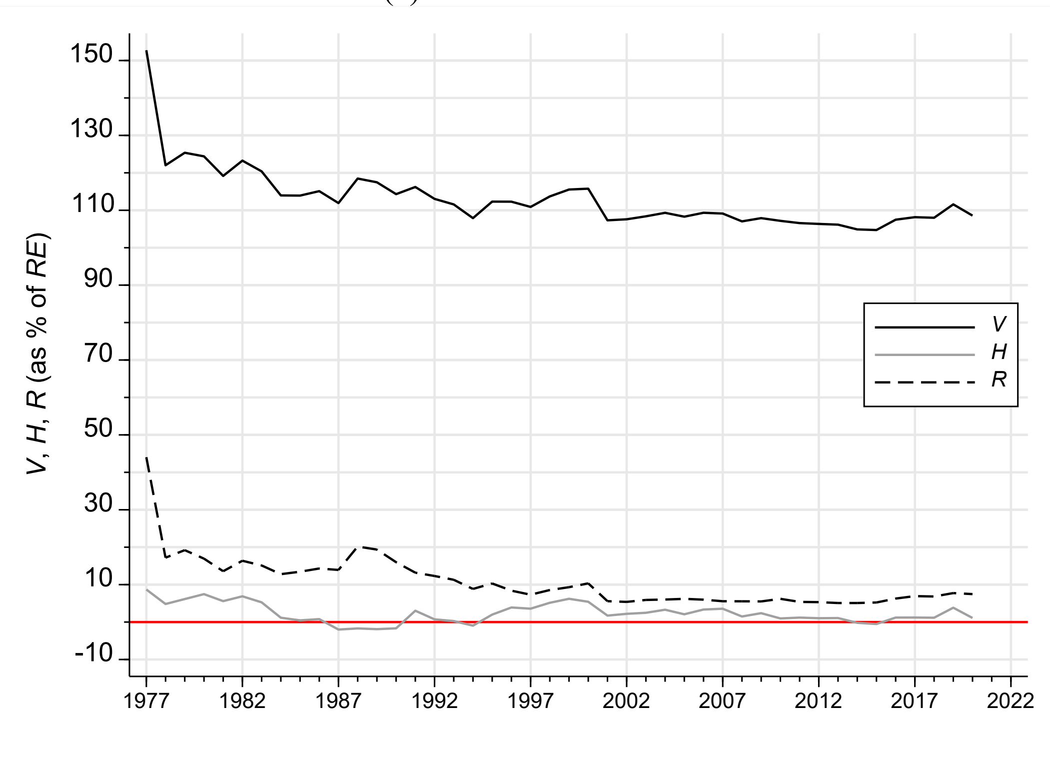
Notes: Bandwidths in pounds are expressed in constant 2020 prices.

Figure 6. Decomposition of the redistributive effect into vertical, horizontal, and reranking effects, UK, 1977–2020

(a) Bandwidth = £10

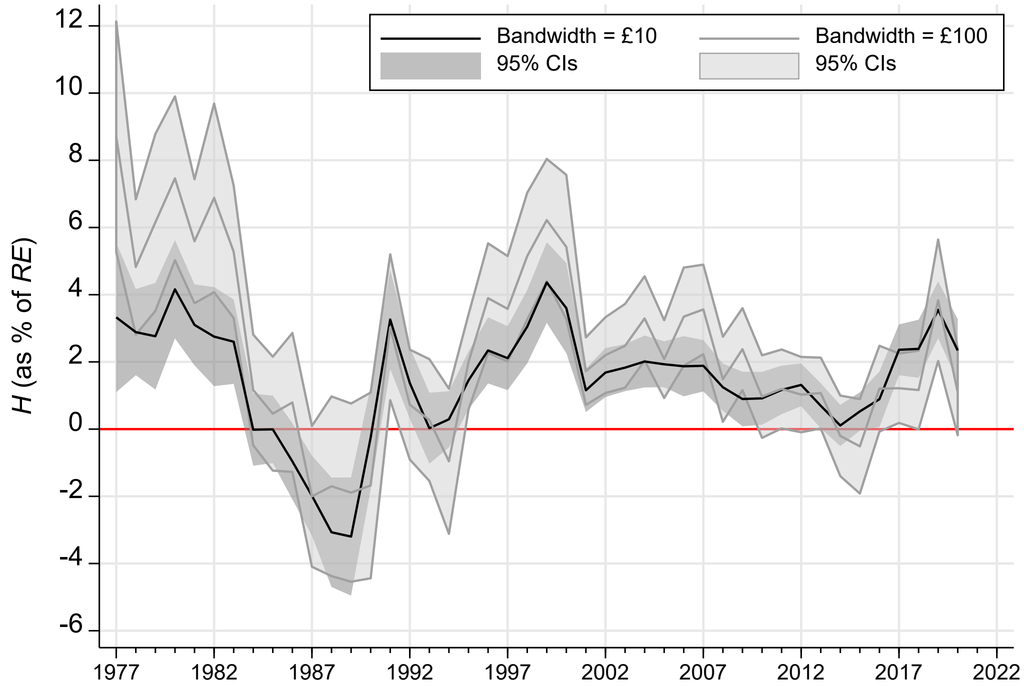


(b) Bandwidth = £100



Notes: Bandwidths are expressed in constant 2020 prices.

Figure 7. Estimates of *H* (as % of *RE*), with 95% confidence intervals, by bandwidth and year



Notes: The shaded areas show 95% confidence intervals calculated using bootstrap standard errors, with 500 replications per year (per bandwidth). Bandwidths in pounds are expressed in constant 2020 prices.

Appendix Table 1. Estimates, by year and bandwidth variant

(a) Bandwidths defined in terms of real income (£10, £100, £1,000, £10,000)

					Bandwidth											
					£10			£100			£1,000			£10,000		
Year	G_X	G_N	RE	R (%)	V (%)	H (%)	H^T (%)	V (%)	H (%)	H^T (%)	V (%)	H (%)	H^T (%)	V (%)	H (%)	H^T (%)
1977	27.5	25.3	2.2	44.0	147.4	3.3	3.8	152.8	8.7	8.8	152.1	8.0	8.4	137.5	–6.6	11.1
1978	27.5	24.8	2.7	17.2	120.1	2.9	3.2	122.0	4.8	5.3	123.7	6.5	6.8	112.0	–5.2	7.9
1979	27.5	25.3	2.2	19.2	122.0	2.8	3.0	125.4	6.2	6.4	126.7	7.5	7.8	114.4	–4.8	8.5
1980	28.8	26.6	2.2	16.9	121.1	4.2	4.6	124.4	7.5	8.0	124.3	7.4	8.0	110.2	–6.7	9.6
1981	29.7	27.2	2.5	13.6	116.7	3.1	3.4	119.2	5.6	6.0	120.8	7.2	7.6	108.5	–5.1	9.4
1982	29.8	27.4	2.4	16.4	119.1	2.8	3.5	123.3	6.9	7.5	123.5	7.2	8.0	109.4	–7.0	10.9
1983	30.0	27.0	2.9	15.1	117.7	2.6	3.3	120.4	5.3	6.3	121.2	6.1	7.3	111.4	–3.8	9.6
1984	29.8	26.8	3.1	12.8	112.8	0.0	1.0	114.0	1.2	2.7	114.1	1.4	2.9	104.3	–8.5	10.2
1985	31.3	28.3	3.0	13.5	113.5	0.0	1.1	113.9	0.5	2.1	114.9	1.4	2.7	106.8	–6.6	8.1
1986	32.6	29.9	2.7	14.3	113.4	–1.0	1.1	115.1	0.8	2.8	114.8	0.5	2.9	107.6	–6.7	8.2
1987	34.1	31.4	2.7	13.9	111.9	–2.0	2.0	111.9	–2.0	2.4	112.6	–1.3	2.4	107.0	–6.9	7.5
1988	35.0	33.1	1.9	20.2	117.1	–3.1	3.1	118.5	–1.7	2.8	117.5	–2.7	3.4	112.8	–7.3	8.8
1989	34.3	32.5	1.8	19.4	116.2	–3.2	3.2	117.5	–1.9	2.5	118.2	–1.2	2.5	114.4	–4.9	8.2
1990	36.4	34.6	1.8	16.0	115.7	–0.3	1.6	114.3	–1.7	2.9	113.7	–2.3	3.3	110.2	–5.8	6.5
1991	35.9	33.8	2.1	13.2	116.5	3.3	3.8	116.2	3.0	4.1	115.3	2.1	3.7	110.6	–2.6	5.2
1992	35.8	33.2	2.5	12.3	113.7	1.4	2.0	113.0	0.7	2.2	112.8	0.5	2.3	108.7	–3.6	5.3
1993	36.4	33.6	2.8	11.3	111.3	0.0	1.0	111.6	0.3	2.0	112.3	1.1	2.8	108.4	–2.9	4.1
1994	35.5	32.3	3.2	8.9	109.1	0.3	1.7	107.9	–1.0	2.6	105.0	–3.8	3.9	100.5	–8.3	8.5
1995	35.4	31.9	3.5	10.3	111.8	1.5	2.1	112.3	2.0	3.6	112.4	2.1	3.7	108.3	–2.1	6.8
1996	35.9	33.0	3.0	8.4	110.7	2.3	2.7	112.3	3.9	4.5	111.8	3.4	4.3	106.6	–1.8	5.1
1997	36.3	33.2	3.0	7.3	109.4	2.1	2.3	110.9	3.6	4.0	110.9	3.6	4.1	107.0	–0.3	4.7
1998	37.2	34.2	3.0	8.6	111.6	3.0	3.3	113.7	5.1	5.6	113.3	4.8	5.3	108.3	–0.2	5.4
1999	37.5	34.8	2.7	9.3	113.7	4.4	4.6	115.5	6.2	6.8	117.8	8.5	9.1	114.8	5.5	9.2
2000	36.7	34.1	2.6	10.3	113.9	3.6	3.8	115.8	5.4	6.3	115.0	4.6	5.7	113.1	2.7	8.6
2001	39.5	35.5	4.1	5.6	106.7	1.2	1.4	107.3	1.7	2.0	106.6	1.0	1.6	104.0	–1.5	2.3
2002	38.5	34.3	4.2	5.4	107.1	1.7	1.9	107.6	2.2	2.6	106.9	1.5	2.4	103.1	–2.3	3.2
2003	38.0	33.6	4.4	5.9	107.7	1.8	2.0	108.4	2.5	2.8	108.1	2.2	2.6	105.0	–0.9	3.1
2004	38.4	33.9	4.5	6.0	108.0	2.0	2.1	109.3	3.3	3.5	108.4	2.4	2.9	105.2	–0.8	2.5
2005	40.1	35.6	4.5	6.2	108.1	1.9	2.0	108.3	2.1	2.4	108.3	2.1	2.5	105.8	–0.4	2.7
2006	41.3	36.9	4.4	6.0	107.9	1.9	2.2	109.3	3.3	3.9	107.7	1.8	2.6	105.0	–0.9	2.9
2007	42.7	38.2	4.5	5.6	107.4	1.9	2.1	109.1	3.6	4.0	108.2	2.6	3.4	105.6	0.1	3.3
2008	40.5	35.4	5.1	5.6	106.8	1.2	1.3	107.0	1.5	1.9	105.5	0.0	1.3	103.2	–2.3	2.8
2009	41.0	36.2	4.7	5.5	106.4	0.9	1.1	107.9	2.4	2.7	107.9	2.4	2.7	105.4	–0.1	3.0
2010	38.9	33.9	5.0	6.2	107.1	0.9	1.2	107.2	1.0	1.5	106.6	0.4	1.2	104.0	–2.2	2.6
2011	38.9	33.6	5.4	5.4	106.5	1.2	1.2	106.6	1.2	1.4	105.3	–0.1	0.8	102.6	–2.8	2.9
2012	39.5	34.1	5.4	5.3	106.6	1.3	1.6	106.4	1.0	1.5	104.9	–0.5	0.8	101.9	–3.4	3.7
2013	40.1	34.7	5.4	5.1	105.8	0.7	0.7	106.2	1.1	1.4	105.2	0.1	0.8	101.3	–3.7	3.8
2014	39.6	34.3	5.3	5.1	105.2	0.1	0.6	104.9	–0.2	0.9	103.3	–1.8	1.9	100.1	–5.0	5.1
2015	40.0	34.7	5.3	5.2	105.8	0.5	0.6	104.7	–0.5	0.6	103.1	–2.1	2.1	99.7	–5.6	5.6
2016	38.4	33.1	5.3	6.3	107.2	0.9	1.0	107.5	1.2	1.6	104.8	–1.5	1.6	102.3	–4.0	4.1
2017	39.7	34.4	5.3	6.9	109.3	2.4	2.7	108.2	1.2	2.1	106.5	–0.5	1.2	103.8	–3.2	3.3
2018	40.0	34.9	5.1	6.8	109.2	2.4	3.1	108.0	1.2	2.6	106.3	–0.5	1.9	103.9	–2.9	3.4
2019	39.8	34.8	5.0	7.7	111.3	3.6	3.7	111.6	3.8	4.2	110.9	3.2	3.5	108.3	0.6	2.4
2020	38.8	33.7	5.0	7.5	109.8	2.3	3.3	108.6	1.1	3.1	107.1	–0.4	2.2	105.0	–2.5	3.0

Notes: (%) denotes values expressed as a percentage of the redistributive effect RE. Bandwidths in pounds are expressed in 2020 prices.

(b) Bandwidths defined in terms of quantile groups (percentile and half-percentile groups)

					Bandwidth					
					Percentile groups			Half–percentile groups		
Year	G_X	G_N	RE	R (%)	V (%)	H (%)	H^T (%)	V (%)	H (%)	H^T (%)
1977	27.5	25.3	2.2	44.0	153.2	9.1	9.4	153.1	9.0	9.3
1978	27.5	24.8	2.7	17.2	125.2	8.0	8.3	124.9	7.7	8.0
1979	27.5	25.3	2.2	19.2	127.0	7.8	8.1	127.0	7.8	8.0
1980	28.8	26.6	2.2	16.9	123.1	6.2	7.0	123.4	6.4	7.1
1981	29.7	27.2	2.5	13.6	119.9	6.3	6.7	119.6	6.0	6.5
1982	29.8	27.4	2.4	16.4	127.4	11.0	11.6	126.8	10.5	11.0
1983	30.0	27.0	2.9	15.1	122.2	7.1	8.0	122.0	6.8	7.8
1984	29.8	26.8	3.1	12.8	115.2	2.4	3.7	115.2	2.4	3.7
1985	31.3	28.3	3.0	13.5	115.6	2.1	3.4	115.6	2.2	3.4
1986	32.6	29.9	2.7	14.3	114.0	–0.3	2.7	114.0	–0.4	2.6
1987	34.1	31.4	2.7	13.9	112.2	–1.8	2.4	112.0	–1.9	2.4
1988	35.0	33.1	1.9	20.2	117.2	–3.0	3.5	117.0	–3.1	3.6
1989	34.3	32.5	1.8	19.4	122.0	2.6	5.4	122.1	2.7	5.4
1990	36.4	34.6	1.8	16.0	116.5	0.5	3.4	116.0	0.0	3.2
1991	35.9	33.8	2.1	13.2	113.5	0.3	3.7	113.6	0.5	3.8
1992	35.8	33.2	2.5	12.3	112.9	0.6	2.4	112.8	0.5	2.3
1993	36.4	33.6	2.8	11.3	112.2	0.9	2.7	112.1	0.8	2.5
1994	35.5	32.3	3.2	8.9	105.6	–3.3	3.5	106.1	–2.8	3.2
1995	35.4	31.9	3.5	10.3	113.0	2.7	4.2	113.1	2.8	4.2
1996	35.9	33.0	3.0	8.4	111.4	3.0	3.8	112.0	3.6	4.3
1997	36.3	33.2	3.0	7.3	110.5	3.2	3.8	110.3	3.0	3.6
1998	37.2	34.2	3.0	8.6	112.3	3.7	4.4	112.8	4.2	4.8
1999	37.5	34.8	2.7	9.3	118.5	9.2	9.7	118.3	9.0	9.5
2000	36.7	34.1	2.6	10.3	118.2	7.9	8.6	118.3	7.9	8.7
2001	39.5	35.5	4.1	5.6	104.8	–0.8	1.8	105.3	–0.3	1.7
2002	38.5	34.3	4.2	5.4	105.2	–0.2	2.5	105.6	0.2	2.4
2003	38.0	33.6	4.4	5.9	107.9	2.0	2.5	107.7	1.8	2.3
2004	38.4	33.9	4.5	6.0	106.3	0.2	2.7	107.7	1.7	2.7
2005	40.1	35.6	4.5	6.2	106.5	0.3	1.8	107.7	1.5	1.9
2006	41.3	36.9	4.4	6.0	106.3	0.3	2.4	107.0	1.0	2.4
2007	42.7	38.2	4.5	5.6	106.1	0.5	2.2	107.2	1.6	2.4
2008	40.5	35.4	5.1	5.6	104.2	–1.3	1.6	104.9	–0.7	1.4
2009	41.0	36.2	4.7	5.5	107.3	1.8	2.3	107.5	2.0	2.5
2010	38.9	33.9	5.0	6.2	105.1	–1.1	1.4	105.8	–0.4	1.1
2011	38.9	33.6	5.4	5.4	102.3	–3.0	3.0	104.7	–0.7	1.0
2012	39.5	34.1	5.4	5.3	102.9	–2.5	2.5	102.8	–2.5	2.5
2013	40.1	34.7	5.4	5.1	100.1	–5.0	5.0	101.5	–3.6	3.6
2014	39.6	34.3	5.3	5.1	100.9	–4.2	4.2	101.5	–3.6	3.6
2015	40.0	34.7	5.3	5.2	101.9	–3.3	3.3	101.7	–3.5	3.5
2016	38.4	33.1	5.3	6.3	102.7	–3.6	3.6	103.9	–2.4	2.4
2017	39.7	34.4	5.3	6.9	102.9	–4.1	4.1	103.2	–3.7	3.7
2018	40.0	34.9	5.1	6.8	104.3	–2.5	2.6	104.4	–2.5	2.5
2019	39.8	34.8	5.0	7.7	109.6	1.8	2.3	109.6	1.9	2.4
2020	38.8	33.7	5.0	7.5	105.9	–1.6	1.9	106.2	–1.3	1.8

Notes: (%) denotes values expressed as a percentage of the redistributive effect RE.