Redistributive Effects of the Shift from Personal Income Taxes to Indirect Taxes: Belgium 1988–93

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Abstract

Between 1988 and 1993, the Belgian personal income tax system and the indirect tax system were reformed to a considerable extent. We use microsimulation models to investigate the impact of the reform on the liability progression and the redistributive effect of the combined tax system. The redistributive effect of personal income taxes decreased, notwithstanding an increase in liability progression. For indirect taxes, both the liability regressivity and the reverse redistributive effect have been enhanced. We use recently developed statistical tests to gauge the significance of the observed changes.

JEL classification: D63, H24.

I. INTRODUCTION

Between 1988 and 1993, the Belgian personal income tax (PIT) system was reformed to a considerable extent. Major elements of this reform were the reductions of the top rates, broadening of the tax base and a move from joint taxation in the direction of individual taxation. The whole set of measures implied a tax cut. The revenue loss was partly compensated by an increase in indirect taxes over the period 1988–93. Simulations show that, despite the increase in indirect taxes, global tax revenue decreased by 4 per cent (see Decoster et al. (1998, p. 65)). The PIT reform, in combination with the reform in the indirect tax system, also led to a change in the mix of both instruments. In 1988, PIT made up 57.8 per cent of the joint PIT and indirect tax revenue. But its share decreased to 53.8 per cent in 1993.[1]

The Belgian PIT reform was very much in line with the Tax Reform Act of 1986 in the US (TRA86), and hence with the type of income tax reform that swept the western countries over a decade ago.[2] The shift in the direction of indirect taxes seems much less common. Although such a shift has been advocated in several other countries, the UK seems to be one of the rare exceptions where it really has been implemented.[3] Therefore we document both reforms separately, and also their joint impact, in this paper.

While one might expect that the increased reliance on indirect taxes implies a regressive move, the impact of the PIT reform and consequently of the global tax reform is much less clear. Indeed, the reduction of the top rates and base-broadening have opposite effects on the tax liabilities to be paid after the reform. Moreover, in the aftermath of TRA86, much attention has been devoted to judging the impact of the PIT reform in the US, and these studies tend to come up with mixed evidence. Some argue that the reform increased progressivity, while others say it went down.[4]

As it turns out, the conclusions about TRA86 tend to depend on the progressivity concept that is used, on a number of data issues such as the exact tax concept, the income concept and the use of equivalence scales, and on modelling assumptions, of which the assumptions about behavioural reactions seem to be the more important ones. Moreover, most studies do not take to heart the recommendation of Bishop et al. (1997) to use statistical tools that check the significance of the changes in progressivity measures. Finally, these TRA86

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[1]These shares are also based on the results of simulations in Decoster et al. (1998).

[2]See Messere (1998, pp. 10–12) and Sommerhalder (1992).

[3]See Messere (1998, p. 8) and Giles and Johnson (1994).

[4]The general expectation at the time of the reform was that TRA86 would increase progressivity (see Pechman (1987)), although the policy proposals themselves mentioned distributional neutrality (see the quote in McLure and Zodrow (1987)). Indeed, many studies found that the reform enhanced progressivity. For a recent survey of a broad range of studies, see Auerbach and Slemrod (1997) and the references therein. Yet the number of studies that conclude that TRA86 decreased progressivity is not negligible (for example, see Bishop et al. (1997)).

studies use different datasets for the pre- and post-reform situation (namely, datasets preceding 1986 and datasets from after 1986). This brings in different pre-tax income distributions, which, of course, are relevant if the objective is an evaluation of the overall change in the after-tax income distribution. But if the sole concern is to separate out the impact of the tax reform itself, these different pre-tax distributions do more harm than good.

In this paper, we try to avoid many of these pitfalls. The reform under study is the 1988 PIT reform in Belgium, followed by indirect tax increases up to 1993. The use of microsimulation methodology allows us to keep the pre-tax income distribution fixed by calculating the tax liabilities of the 1988 and 1993 systems on the same dataset. By holding everything else constant (for example, changes in primary incomes), we can focus exclusively on the policy change of interest. The simulations are carried out by means of two different microsimulation models, one for PIT and one for indirect taxes. These models run on two different underlying datasets, but we combine the simulated tax liabilities into one single dataset with the aid of a statistical matching technique.

Our aim is to sketch the impact of the tax reform on the redistributive power of the system. A quick plunge into the literature shows how manifold are the meanings attached to the term 'redistributive'. Especially in the vulgarising papers and publications, the distinction between 'redistribution' and 'progressivity' is often lost from sight.[5] The basic distinction is between the change in the after-tax income distribution, produced by the tax system, and the disproportionality of the tax system, measured as the deviation of the distribution of tax shares from the shares obtained from an equal-yield proportional tax. Following Lambert (1993), we call the first concept 'redistributive effect' and the second 'liability progression'.

The Reynolds–Smolensky index and the Kakwani index respectively are one set of possible indices to summarise these two characteristics of a tax system, and the relation between the two is well understood. In this paper, we present these indices and their standard errors, for PIT, indirect taxes and the global system before and after the reform. But our micro-data also allow us to go further. In addition to the indices themselves, we provide the detailed Lorenz and concentration curves underlying them. This not only gives a more detailed picture of the effect of the tax reform through the income scale. The main advantage lies in bypassing the choice of specific aggregation procedures, unavoidably associated with index values. In this, we follow the approach fruitfully applied by Bishop et al. (1997) for TRA86. Moreover, some recently

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[5]Many policy proposals contain prescriptions such as 'designing the tax reform as distributionally neutral', notwithstanding the lack of a precise description of what is meant by this. TRA86, however, is one of the rare exceptions that did specify this distributional neutrality — namely, as equal percentage reductions in tax liabilities at all income levels (see McLure and Zodrow (1987, p. 44)). Clearly, this refers to keeping the *liability progression* constant.

published papers provide the tools to take into account the importance of the sampling errors when Lorenz and concentration curves are compared.[6]

In Section II, we discuss the simulated reforms. Section III deals with the data and the simulation models that have been used. The methodology to measure the redistributive effect and the liability progression is summarised in Section IV and empirically applied to the Belgian tax reform in Section V. Section VI concludes.

II. THE SIMULATED TAX REFORMS

1. The Reform of the Personal Income Tax System[7]

The first major element of the tax reform was 'base-broadening'. Many deductions, applied to gross income, were discarded and replaced by tax credits. Therefore the concept of 'taxable income' was altered significantly by the reform. The reform also tightened the possibilities for deducting costs from professional income, such as expenses on visiting restaurants and on professional clothing. Before the reform, expenses on life insurance contracts were treated partly as a deduction and partly as a tax credit, while, after the reform, they are treated entirely as a tax credit. This change has led to a less favourable treatment of life insurance contracts in the tax system after the reform. In the 1988 PIT system, capital redemptions due to mortgage loans, payments to group insurance contracts and contributions to private pension funds could be deducted. The 1993 PIT system uses tax credits instead of a deduction in all these cases. The reform also installed a more generous deduction for charity gifts, and some expenses for childcare could be deducted after the reform but not before. In general, however, the deduction possibilities are more restricted after the reform.

Second, taxable income was imported into different tax schemes before and after the reform. Three major differences can be distinguished:

- A thorough *restructuring of tax rates* — broader and fewer brackets, lower marginal tariffs at the top.
- The zero-rate bracket, applied before the reform, was abolished. After the reform, *basic allowances* were installed to compensate for family structure (for example, spouse and dependent children).

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[6]See Bishop, Chow and Formby (1994) and Davidson and Duclos (1997).

[7]We sketch the major differences between the 1988 and 1993 PIT systems. Hence, so to speak, *the reform* refers to all the measures that have been implemented between 1988 and 1993, although they have not been realised by a single tax reform act. Note that if we refer to 1988 or 1993 for the PIT system, this implies reference to the administrative tax years 1989 or 1994 respectively. Although we do not consider the benefit part of the disposable income generation process, we do, of course, take into account any change in the tax treatment of replacement incomes and benefits.

- Full *separate taxation* of the main income earned by spouses (labour income, unemployment benefits, pensions, etc.) after the reform.

The reform has reduced the number of tax brackets from 14 to seven. The changes for higher income levels are especially striking. Before the reform, four different rates, ranging from 56.5 per cent to 70.8 per cent, were applied on income above BEF 1,574,000. After the reform, these income levels only face rates of 52.5 per cent or 55 per cent.

Before the reform, the first bracket of the scheme (up to BEF 120,000) was a zero-rate bracket and dependent children entitled the taxpayer to tax credits. The reform substituted 'exemptions from the bottom up' for the zero-rate bracket.[8] This basic allowance varies with household composition (i.e. by marital status and whether there are dependent children). In 1993, it amounted to BEF 186,000 for a single person and BEF 146,000 for each partner of a married couple. Dependent children pushed the exemption level up by BEF 39,000, BEF 62,000, BEF 127,000 and BEF 141,000 for the first, second, third and fourth child respectively.

Full separate taxation of professional income and the creation of the 'marriage fraction' for spouses was one of the core elements of the PIT reform. Before the reform, a rather low joint income ceiling determined whether the professional income of a two-income-earner family was taxed jointly or separately. Above the threshold, joint taxation was the rule, which, in a progressive system, could lead to a large discrepancy in the amount of taxes paid by a married couple as compared with a cohabiting, but non-married, couple. To cope with this problem, the new system attributes to each partner the income components that are associated with his or her own professional activity. This separate income concept covers wages and salaries paid to employees but also replacement incomes, such as unemployment benefits and retirement pensions. Other sources of income, such as real estate income or income from movable property, are still attributed to the partner with the highest amount of professional income. To compensate families with only one income earner for this 'favourable' tax treatment of double-income families, the system of 'marriage fraction', designed to cope with unequally distributed household income, was continued and enlarged. If one of the spouses earns less than 30 per cent of the total amount of professional income of the couple, this partner is

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[8]The description 'exemptions from the bottom up' has been used in official texts in Belgium to distinguish this basic allowance from ordinary exemptions and deductions on the one hand, and credits on the other hand. Ordinary exemptions and deductions lead to a reduction in the tax liability, which is determined by the *marginal* tax rate (hence 'at the top'). Exemptions 'from the bottom up' determine a tax *credit* by calculating the tax liability on this exempted income, starting with the lowest marginal rates first (hence 'from the bottom up'). This tax credit is then subtracted from the tax liability obtained from the taxation of the taxable income without the exemption.

attributed an amount as if he or she had earned this 30 per cent.[9] The income of the other partner is reduced by this amount. This reshuffling of taxable income among spouses was limited to BEF 297,000 in the 1993 PIT system.

2. The Reform of the Indirect Tax System

The main change in the indirect tax system took place in April 1992. This reform was intended to bring the Belgian indirect tax system more into line with EC recommendations that prescribed a normal rate of at least 15 per cent and one or two rates of at least 5 per cent. Before the reform, seven different VAT rates were applied (0, 1, 6, 17, 19, 25 and 33 per cent). The newly installed government decided to drop the 17, 25 and 33 per cent rates. The normal rate became 19.5 per cent. The reduced rate of 6 per cent was maintained and a second reduced rate, of 12 per cent, was introduced. Hence five different VAT rates still applied after the reform (0, 1, 6, 12 and 19.5 per cent).

To compensate for the decrease in the VAT rate on road fuels, excises on these products were simultaneously increased. This increase in excises was only one step of a continuous increase in excise taxation on these products during the period of investigation. Per litre of petrol, the consumer paid an excise of BEF 11.2 in 1988 and BEF 18.45 in 1993. For diesel, the figures are respectively BEF 5.25 in 1988 and BEF 11.33 in 1993. The same continuous increase in excise holds, to a lesser extent, for cigarettes, although in this case it has been offset partially by a decrease in the *ad valorem* tax. The excises on most other products remained constant throughout the studied period, which implies an effective decrease in tax burden. By means of the microsimulation model for indirect taxes described in the next section, we have calculated the impact of these changes on consumer prices, under the assumption of fixed producer prices. The consumer prices of petrol, diesel and tobacco products increase substantially, by 31 per cent, 39 per cent and 12 per cent respectively. The abolition of the 33 per cent and 25 per cent VAT rates shows up in a price decrease for durables of 3 per cent.

III. THE DATA AND SIMULATION OF THE REFORMS

We use two different microsimulation models, with different datasets, to simulate the PIT reform and the indirect tax reform. We combine these datasets using a statistical matching procedure, to end up with a single dataset that can be used to evaluate both reforms.

Personal income taxes are simulated with the microsimulation model, SIRe, which uses a sample of administrative data.[10] This sample, referred to as IPCAL,

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[9]Note that this system also applies for two-income-earner families if the marriage fraction produces a lower tax liability than separate taxation does.

[10]See Standaert and Valenduc (1996) for more information on SIRe.

consists of 10,343 tax returns filed in 1994.[11] As a consequence, the units of observation are administrative units. In principle, these units are individuals, since each Belgian citizen who gains a sufficient amount of income has to file a tax return separately. However, married couples file only one tax return. People with income below some threshold do not have to file a tax return.[12] Therefore the sample is not representative of the whole population.

Both the 1988 and 1993 PIT systems have been simulated on the same dataset.[13] Since no behavioural responses were available in SIRe, gross income is kept constant between 1988 and 1993.

The indirect tax reforms are simulated with the microsimulation model, ASTER.[14] The basic dataset of this model is a household budget survey that covers 3,235 households and has been designed as a representative sample of all households living in Belgium. A household is defined as all people living under the same roof, using the same accommodation and deciding their expenditures commonly. The households in the survey have been asked to register their expenditures between May 1987 and May 1988. Besides the very detailed expenditures at the household level, the budget survey also contains information on labour income and most social security benefits of the individual household members. However, since all income information in the budget survey is net of taxes, it was not possible to simulate the PIT reform on this dataset. Hence we only used the budget survey to simulate the indirect tax liabilities before and after the reform of the indirect tax system. The detailed demand system available in ASTER allowed us to take account of behavioural reactions to the change in relative prices, and real income. The total amount of household expenditure was kept constant for the simulation.[15]

A major problem arises because the datasets have different units of observation. The budget survey contains households. IPCAL is a set of administrative units. Since the information needed to combine these administrative units in IPCAL into households is not available, households in the budget survey are first split into administrative units, similar to those used in IPCAL. To do this, we apply the administrative rules to the information that is

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[11]Hence the reported income figures are expressed in 1993 prices.

[12]For some people, such as those receiving only replacement income, it is obvious that they will not have to pay income taxes. After a number of years, these people no longer receive a tax form from the administration. They only have to contact the administration if their income condition has changed. The parameters of the tax system (and hence the rules used by the administration) determining which people do not receive a tax form did not change in the period under consideration.

[13]To express nominal figures in the tax legislation of both systems at the same level, we used the change in the consumption price index. This index increased from 100 to 115.8 between 1988 and 1993. See Ministerie van Financiën (1994, p. IV.4). Between 1988 and 1993, the important parameters of the tax system, such as brackets, allowances and deductions, were fully indexed.

[14]See Decoster (1995) and Decoster, Delhaye and Van Camp (1996) for more information on ASTER.

[15]This amounts to assuming that the change in disposable income caused by the PIT reform is completely absorbed into savings.

available in the budget survey. We then inflate the nominal variables in this disentangled budget survey, to make the levels comparable to those observed in IPCAL.[16] Since the adapted budget survey and IPCAL have a number of variables in common, we can establish a link between the two datasets by minimising a distance function over these common variables. In Decoster et al. (1998) and Decoster and Van Camp (2000a), we describe how we have applied a statistical matching technique to combine the datasets.[17] With the aid of this link, we can transfer the simulated PIT liabilities from IPCAL to the disentangled budget survey. Then simply summing the PIT liabilities of all administrative units within a single household results in PIT liabilities expressed at the household level. Hence, after this operation, we dispose of PIT and indirect tax liabilities for all households in the budget survey, both before and after the reform.

IV. MEASUREMENT OF THE REDISTRIBUTIVE EFFECT AND OF LIABILITY PROGRESSION

To provide insight into the operation of the different tax systems, we compare distributions realised under the actual tax system with those that would be achieved under an equal-yield proportional tax. It is common practice to implement this idea with the aid of the Lorenz curve of pre-tax incomes and concentration curves of post-tax incomes and tax liabilities.[18] This approach provides an intuitive view of the impact of the different tax systems. Moreover, statistical tools to test whether or not these curves differ significantly are directly available.

1. Definition of the IR*(p)- and* TR*(p)-Curves*

To measure the redistribution of after-tax incomes caused by the non-proportional system in comparison with the proportional one, one compares the ordinates of the Lorenz curve of pre-tax income, *X*, with those of the concentration curve of post-tax income, *M* ($= X–T$, where *T* is the tax liability). This comparison reveals how the post-tax income shares of the actual tax system are distributed, compared with those of the proportional tax system. We capture this difference between the two ordinates at a given quantile, *p*, by *IR(p)*.[19]

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[16]The factor we use to inflate these figures is 1.404, which captures the nominal growth of national income in the National Accounts between 1987–88 and 1993.

[17]On statistical matching, see, for example, Rodgers (1984).

[18]See, among others, Kakwani (1986), Pfähler (1987), Duclos (1993), Lambert (1993, Ch. 7) and Bishop et al. (1997). In this section, we only assemble the elements from this literature that are relevant for the empirical section. Our notation follows Lambert (1993) quite closely.

[19]The exact definition of *IR(p)* is the ordinate of the concentration curve of post-tax income minus the ordinate of the Lorenz curve of pre-tax income.

Figure 1 illustrates the three curves. The measure $IR(p)$ can be interpreted as the fraction of post-tax income that is shifted from high incomes (the top $100(1-p)$ per cent) to low incomes (the bottom $100p$ per cent) because of the disproportionality of the tax system.

FIGURE 1

Post-Tax Concentration Curve, Pre-Tax Lorenz Curve and the Difference between Them
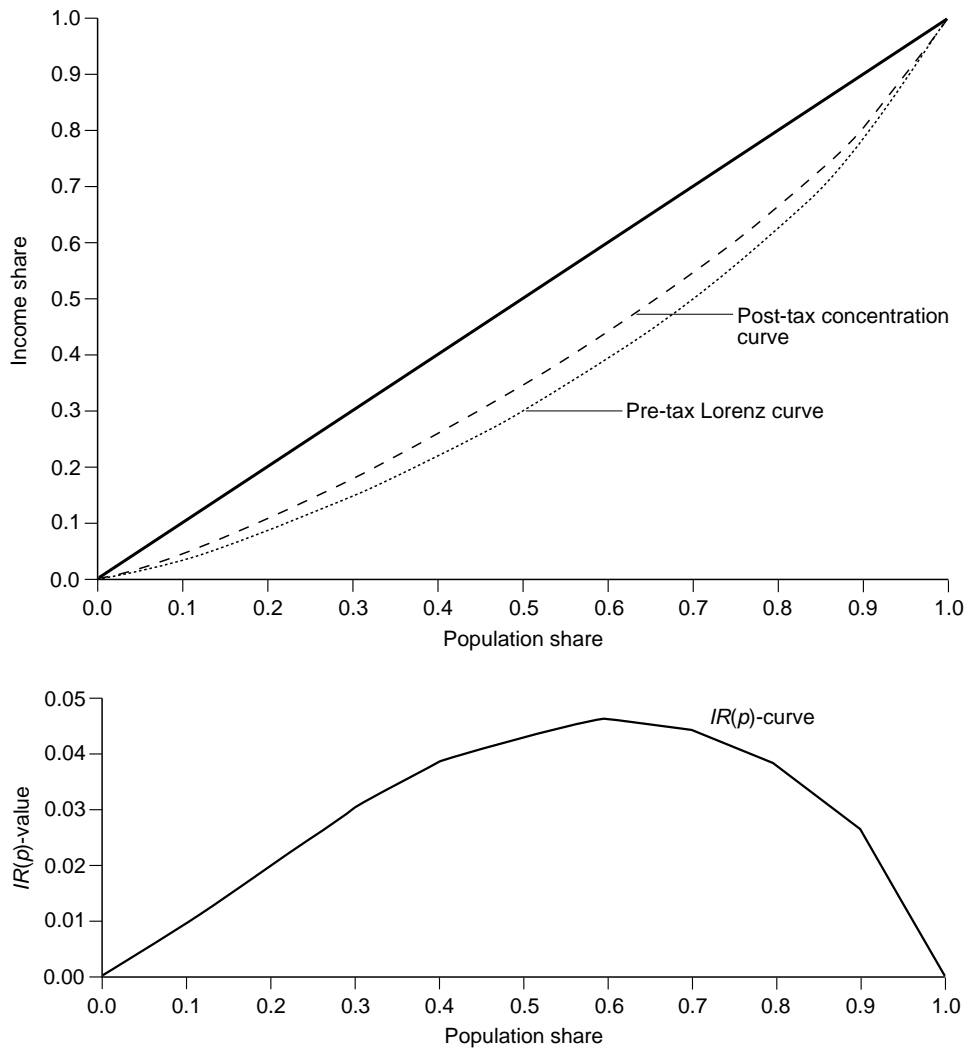
To end up with a single index value for the redistributive effect, it is common practice to aggregate $IR(p)$-values over the p-range of quantiles. Best known in this case is the index proposed by Reynolds and Smolensky (1977), which equals twice the difference between the two curves in the upper panel of Figure 1. We denote this index of redistribution by Π^{RS}.

Of course, producing an aggregate index of the redistributive effect comes at a price, and Π^{RS} is to the $IR(p)$-curve as the Gini coefficient is to the Lorenz curve: detail is lost and eventually more general dominance results are forgone in the process of aggregation. Therefore we present not only the index Π^{RS} (in Section V(1)) but also the $IR(p)$-curve itself (in Section V(2)).[20]

The redistribution of post-tax income captured by $IR(p)$ and Π^{RS} is ultimately based on the *disproportionality* of the tax liabilities. Hence, alternatively, one can also focus on the concentration curve of these tax liabilities. The comparison of the tax concentration curve and the Lorenz curve for pre-tax income yields the difference between the tax shares of the actual tax system and those of the proportional tax system. Similarly to the $IR(p)$-curve, we have defined the measure $TR(p)$ to record this difference. The $TR(p)$-curve is to be interpreted as the fraction of the total tax burden that is shifted from low incomes (the bottom $100p$ per cent) to high incomes (the top $100(1-p)$ per cent) because of the disproportionality of the actual tax system.[21]

Integration of $TR(p)$ over the p-range now yields the Kakwani (1977) index of liability progression, which is twice the area under the $TR(p)$-curve. We denote it by Π^{K}. In Section V(1), we present the Π^{K}-indices before and after the reform; in Section V(3), we sketch the $TR(p)$-curves to investigate the dominance character of the results.

It is well known that $IR(p)$ and $TR(p)$, and hence Π^{RS} and Π^{K}, are intimately related by means of the average tax rate, t, in the following way:[22]

$$(1) \qquad IR(p) = \frac{t}{1-t} TR(p),$$

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[20]Since $IR(p)$ is a comparison between a post-tax and a pre-tax distribution, it might also be interpreted as the change in post-tax *income inequality* because of taxation. However, if there is reranking, it is well known that $IR(p)$ provides a biased estimate of this change in inequality. See, for example, Lambert (1993, p. 185).

Reranking can be captured as the difference between the post-tax income *concentration* curve and the post-tax income *Lorenz* curve (see Duclos (1993, p. 353) and Duclos (2000) for a possible interpretation of this reranking measure). We could never reject the hypothesis that this difference is equal to zero (see Decoster and Van Camp (2000b)). Therefore we can also use the $IR(p)$-values to judge the impact of the different tax reforms on inequality of post-tax incomes.

[21]The exact definition of $TR(p)$ is the ordinate of the Lorenz curve of pre-tax income minus the ordinate of the concentration curve tax liabilities. In a progressive system, the lower income groups bear a share of the total tax receipts that is smaller than their share in taxable income. Hence the $TR(p)$-values for a progressive system are positive.

[22]See Lambert (1993, pp. 183–4)

which, after integration, becomes

$$(2) \qquad \Pi^{RS} = \frac{t}{1-t} \Pi^{K}.$$

Both equations (1) and (2) reveal the importance of the average tax rate, t, in the transformation of liability progression into the redistributive effect. Hence, in the evaluation of a single tax system, both measures will show up with the same sign. But if the values are compared over tax systems with different average tax rates (for example, before and after a non-revenue-neutral tax reform), it is perfectly possible for $IR(p)$ to decrease while $TR(p)$ increases. The same holds, of course, for Π^{RS} and Π^{K}.[23]

2. Estimation of and Statistical Inference on Curves and Indices

We write $L_{X;X}(p)$ to denote the ordinate of the Lorenz curve at quantile p. The first subscript of $L_{.;.}(p)$ refers to the variable that is used to order the data in ascending order. The second subscript refers to the variable of analysis. $F(x)$ refers to the cumulative distribution function of the variable X, so that quantile p is defined by $p = F(y)$.

The ordinates of the Lorenz and concentration curves are estimated as the fraction of two sums. The following equation gives the expression for the estimates of the ordinates of the Lorenz curve for pre-tax income:

$$(3) \qquad \hat{L}_{X;X}(p) = \frac{\sum_{i=1}^{n} w_i x_i I_{[0,\hat{y}]}(i)}{\sum_{i=1}^{n} w_i x_i}, \qquad 0 \leq p \leq 1 \quad \text{and} \quad p = \hat{F}(\hat{y}),$$

where

$$(4) \qquad I_{[0,\hat{y}]}(i) = \begin{cases} 1 & \text{if} \quad x_i \leq \hat{y} \\ 0 & \text{otherwise} \end{cases}.$$

In these equations, n is the sample size, w_i refers to the sample weight of observation i and $I_{[0,\hat{y}]}(i)$ is an indicator function. Estimated values are denoted by $\hat{}$. Similar estimators for the concentration curves $L_{X;T}(p)$ and $L_{X;M}(p)$ are obtained if one replaces pre-tax income, x_i, in equation (3) with tax liability, t_i,

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[23]See Formby, Smith and Thistle (1990) and Silber (1994) on this point.

and post-tax income, m_i, respectively. Finally, if one substitutes m for x and the distribution function for post-tax income, G, for the one for pre-tax income, F, in equations (3) and (4), one obtains an estimator for the Lorenz curve, $L_{M;M}(p)$.

We obtain an estimate of the curves as a whole by combining a number of ordinates, estimated for different values of p. Beach and Davidson (1983) derived that, asymptotically, vectors of such estimators are multivariate normally distributed. Davidson and Duclos (1997) extended these results for vectors with differences between two dependent ordinate estimators, as is required for differences between estimators of Lorenz and concentration curves.[24] They proved that such vectors have an asymptotically multivariate normal distribution as well and gave an expression for the asymptotic covariance matrix. All elements of the covariance matrix are estimated straightforwardly from the expressions they provided.[25]

Since there is no obvious criterion to select the population shares for which to estimate ordinates, any choice is arbitrary. We estimate the ordinates corresponding to *decile* population shares. Our joint null hypothesis is that two curves do not differ. We follow Bishop, Chakraborti and Thistle (1989) by testing this joint null hypothesis through sub null hypotheses at each estimated point of the curve. Hence, with 10 deciles, we build our joint hypothesis on nine sub null hypotheses. If at least one of these sub null hypotheses is rejected, the joint null hypothesis of no significant difference between the curves is also rejected.

Contrary to the approach in Beach and Davidson (1983), where one single test decides on the rejection or not of the joint null hypothesis, our approach through several sub null hypotheses allows us to distinguish between several alternatives: positive dominance, negative dominance and crossing of the curves. We conclude that there is positive dominance if we reject a sub null hypothesis at at least one point and if all significant differences are positive. Conversely, we conclude that there is negative dominance if there is a significant difference at at least one point and if all significant differences are negative. If we observe

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[24]Bishop, Chow and Formby (1994) provide similar theorems, but they do not give an explicit expression for the elements of the covariance matrix, which makes their results less accessible for empirical implementation.

[25]Davidson and Duclos (1997) suggested estimating the quantile values within the covariance matrix, such as $E(Y | Z = G(p))$, with the aid of a Kernel estimator. This is done only when the *quantile values of concentration curves* are estimated. We use a Gaussian Kernel and determine the band width by means of expression 3.28 on page 45 of Silverman (1986).

The use of the Kernel estimator only to estimate the quantile values of concentration curves, and not for the values of the *ordinates* of the curves nor for the Lorenz curves, is, besides the appeal of simplicity, based on at least two other arguments. First, it reflects the fact that the ordering variable (for example, *Z*) and the variable of analysis (for example, *Y*) converge differently from their true value. Second, one may assume that there is more uncertainty when a point value has to be estimated (as is the case for a quantile value) instead of a sum of these points (as is the case when ordinates are estimated).

significant positive differences at some points and significant negative differences at other points, we conclude that curves are crossing.

In order to test our joint null hypothesis, we need appropriate significance levels at each of the points where a sub null hypothesis is tested. Indeed, choosing a 5 per cent significance level for each test of a sub null hypothesis leads to a significance level of more than 5 per cent for the joint test. Denoting the significance level of each of the sub null hypothesis tests by α and the number of sub null hypotheses by k, the joint significance level equals $1-(1-\alpha/k)^k$, which is smaller than α. Hence, to maintain the significance level at 5 per cent for the joint test, we need to take critical values from the *joint* distribution of the estimates. In this case, this amounts to the multivariate analogue of student t — the student maximum modulus (SMM) distribution — and we have to select the critical value corresponding to the number of sub null hypotheses in the joint test. For three, six, 10, 15 and even more sub null hypotheses, critical values for the SMM distribution are available in Stoline and Ury (1979). For numbers of sub null hypotheses in between these values, one cannot retrieve the critical values from their tables. Some authors (for example, Bishop, Chow and Formby (1994)) have solved this problem by linearly interpolating between the critical values listed in Stoline and Ury (1979). An alternative approach consists of constructing Bonferroni t-intervals: divide the significance level required for the joint test, α, by the number of sub null hypotheses to be tested and retrieve the critical values from the univariate distribution of each of the individual estimates. Since $1-(1-\alpha/k)^k < \alpha$, this approach is more conservative than using the values of the SMM distribution. Hence the significance level of the joint test is smaller than the joint significance level one originally aims at. The joint null hypothesis of no difference between the two curves will be rejected less often.

We have nine sub null hypotheses, which is a missing value in Stoline and Ury (1979). Since we prefer a more conservative test rather than linear interpolation of the critical values, we construct Bonferroni t-intervals. We choose α equal to 5 per cent. The critical value for a two-sided test with nine sub null hypotheses and infinite degrees of freedom is then 2.78.[26]

For the *aggregate* indices (Reynolds–Smolensky and Kakwani) and their corresponding standard errors, we have the choice between two approaches: either use the nine estimates of the ordinates of the Lorenz and concentration curves, or use all observations in the sample. Duclos (1997) showed that these aggregate indices and the corresponding standard errors can be derived from the ordinate estimates. But this entails a loss of information, compared with

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[26]See Seber (1977, p. 131, Table 5.1).

procedures that use all observations in the sample. Therefore we follow Bishop, Formby and Zheng (1998), who demonstrated the asymptotic normality of Reynolds–Smolensky and Kakwani indices and provided expressions that use all sample values to determine the standard errors of these indices.

V. EMPIRICAL RESULTS

We order households on the basis of equivalised pre-tax income. This is constructed as the sum of DI_i^B, the disposable income of household i as recorded in the budget survey, and PIT_i^B, the PIT liability of household i paid before the PIT reform.[27] We use the superscript B to denote the situation before the reform and a superscript A for the situation after the reform. To equivalise, we use the OECD equivalence scale.[28] The tax liabilities are also equivalised.

1. Aggregate Measures of the Redistributive Effect and of Liability Progression

Table 1 presents the Reynolds–Smolensky measures of the respective tax systems. Not surprisingly, the PIT system shifts, on average, post-tax income from top to bottom, while the reverse is true for the indirect tax system. This holds both before and after the reform. The PIT system being quantitatively more important than the indirect tax system (see Table 2 for the average tax rates), the combined tax system also shifts post-tax income from top to bottom before and after the reform. Yet the reform reduced the positive value of the Reynolds–Smolensky for PIT and it increased (in absolute value) the negative value of this index for the indirect tax system. Consequently, the reform eroded the redistributive effect of the combined system. The standard errors, presented in Table 1, indicate that the index values and the changes induced by the reform are all statistically different from zero.[29]

Equation (2) clearly shows the two basic components of the redistributive effect of a tax system: the interplay of the average tax rate (given in Table 2) and liability progression. The latter is presented in the form of the Kakwani index in Table 3. Since the average tax rate is always positive, the Kakwani index appears with the same sign as the redistributive effect in Table 1. Personal income taxes

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[27]We do not use the pre-tax income concept from the fiscal dataset IPCAL, since some relevant income components, such as family allowances, are not taxed and thus not available in IPCAL. Disposable income in the budget survey covers all household income components, including transfers and non-earned income. Our equivalised pre-tax income is therefore different from gross market income.

[28]In this scale, the first adult is given a value of 1, each subsequent adult gets a weight of 0.7 and each child counts for 0.5. One is considered a child until the age of 13. Of course, we cannot exclude the possibility that our results are sensitive to the choice of the scale.

[29]A two-sided test with $\alpha = 0.05$ has been applied, the critical value being $t_\infty^{0.025} = 1.96$.

TABLE 1

Reynolds–Smolensky Measures for PIT, Indirect and Global Tax Systems

	Personal income taxes	*Indirect taxes*	*Global taxes*
Redistributive effect before the reform	0.059570 (0.001860)	−0.007691 (0.000354)	0.055924 (0.001991)
Redistributive effect after the reform	0.058233 (0.001719)	−0.008301 (0.000360)	0.054069 (0.001849)
Change in the redistributive effect because of the reform	−0.001337 (0.000369)	−0.000610 (0.000035)	−0.001855 (0.000409)

Note: Standard errors are given in parentheses.

TABLE 2

Average Tax Rates

	Personal income taxes	*Indirect taxes*	*Global taxes*
Before the reform	0.2264	0.0766	0.3030
After the reform	0.2108	0.0804	0.2912
Change	−0.0156	0.0038	−0.0118

TABLE 3

Kakwani Indices for PIT, Indirect and Global Tax Systems

	Personal income taxes	*Indirect taxes*	*Global taxes*
Liability progression before the reform	0.203579 (0.005349)	−0.092761 (0.004616)	0.128685 (0.003980)
Liability progression after the reform	0.218064 (0.005491)	−0.094936 (0.004442)	0.131627 (0.003937)
Change in the liability progression because of the reform	0.014485 (0.000947)	−0.002175 (0.000468)	0.002942 (0.000732)

Note: Standard errors are given in parentheses.

and the combined system are liability progressive. The indirect tax system is regressive. This holds both before and after the reform. But, due to changes in average tax rates, the reform can result in opposite changes in the Kakwani and Reynolds–Smolensky measures. For PIT, this is indeed the case. Since the liability progression of PIT has been increased by the reform, the erosion of the

redistributive effect of PIT is entirely due to the lower average tax rate. For indirect taxes, both liability regressivity and the average tax rate increased, leading to an enhancement of the negative redistributive effect. Also, the Kakwani indices, and the changes therein because of the reform, are found to be statistically different from zero.

These figures contradict the common opinion that the Belgian tax reform of the 1980s reduced redistribution because personal income taxes became less progressive. The reform did indeed lead to a smaller redistributive effect, but this occurred notwithstanding the increased liability progression of PIT. The erosion of the redistributive effect of the global system is due to a combination of two factors: on the one hand, the reduction of the tax rate of the progressive PIT; on the other hand, the increased reliance on the regressive indirect tax system, which became still more regressive because of the reform.

The Reynolds–Smolensky and Kakwani indices are one specific way of aggregating the underlying $IR(p)$- and $TR(p)$-values. Looking at the curves themselves not only gives a much more detailed picture of what is happening at different points of the income distribution, but also allows us to test whether the above conclusions are robust with respect to the specific aggregation procedures. This is the topic of subsections 2 and 3.

2. Dominance Results for IR*(p)*-Curves

Figure 2a shows the nine estimated ordinates of the post-tax income redistribution curves before the reform.[30] None of the three $IR(p)$-curves changes sign. This provides us with a dominance result, and hence a generalisation of the results obtained in subsection 1. Besides the specific aggregation implicit for Reynolds–Smolensky and Kakwani indices, the conclusion of a positive redistributive effect for PIT and a negative one for indirect taxes would result for any other aggregation procedure with positive weights at each quantile share.[31] Moreover, we can always reject the hypothesis that the curves as a whole are equal to zero.[32]

The estimated $IR(p)$-curves after the reform lead to the same conclusion. Moreover, the post-reform curves always lie below their pre-reform counterparts. Since the difference between the pre- and post-reform curves is too small to be visible in the same graph, we have chosen to present, in Figure 2b, the difference $IR^A(p) - IR^B(p)$.

Take the case of PIT first. At each p-quantile, the curve in Figure 2b is negative. This means that, throughout the whole income range, less post-tax

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[30]The numbers underlying Figures 2a and 2b can be found in Tables A.1 and A.2 of the Appendix.
[31]See Duclos (1993).
[32]The detailed test results are given in columns 4, 8 and 12 of Table A.1 in the Appendix.

FIGURE 2a

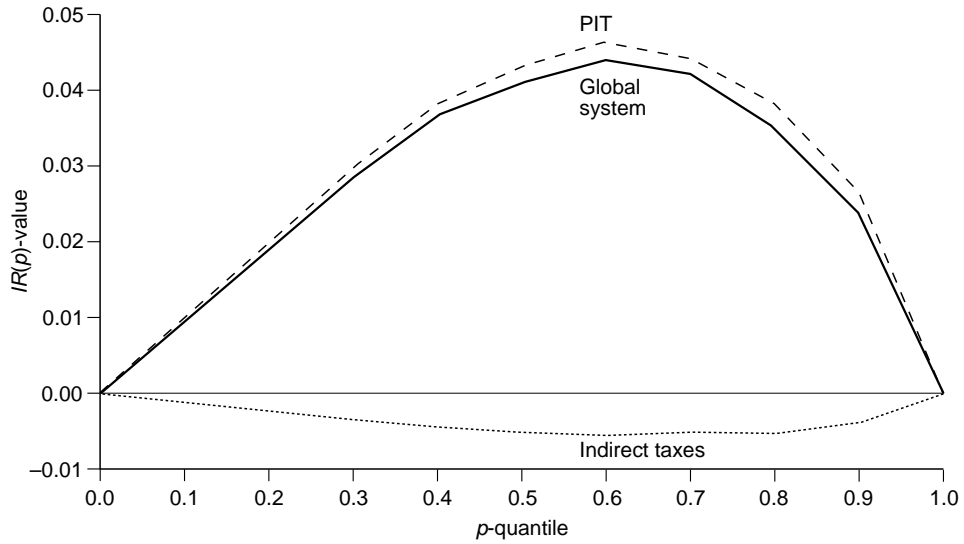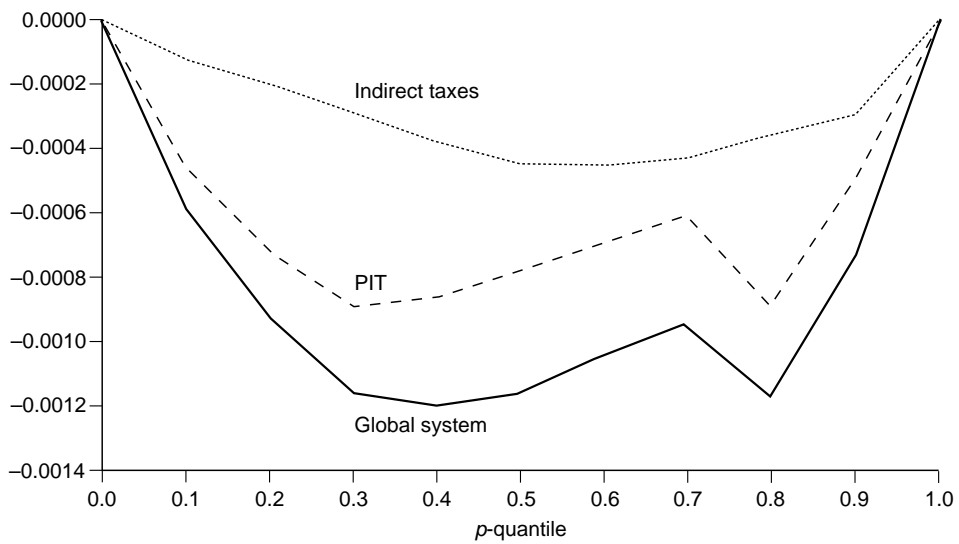**$IR(p)$-Values before the Reform**

FIGURE 2b

Change in $IR(p)$-Values due to the Reform

income is redistributed from top to bottom by PIT after the reform. One can say that the redistributive power of PIT decreased at all income levels. Hence also the change in the Reynolds–Smolensky measures, described in subsection 1, can be generalised on the basis of this dominance result. But the statistical test of $IR^B(p)$ being not significantly different from $IR^A(p)$ at all points cannot be rejected. The reason is a non-rejection at the four highest p-quantiles.[33] Testing a similar hypothesis over the bottom half of the distribution, the hypothesis that $IR^B(p)$ is not significantly different from $IR^A(p)$ can be rejected.[34] Hence there is evidence to say that there has been a significant decrease in the redistributive impact of PIT in the bottom half of the distribution.

The kink in the curve that plots the change in $IR(p)$ at the point $p = 0.8$ might be somewhat startling. Yet, if one realises that the reform was also correlated with non-income characteristics, non-monotonicity should not come as a surprise. One explanation, arising from a detailed analysis of the eighth decile, is the fact that the share of married couples is lower in this decile than in the surrounding ones.

For indirect taxes, the curve in Figure 2b lies under the horizontal axis everywhere. The overall statistical test reveals that the curve is statistically different from zero. Hence one can safely say that the redistribution from bottom to top by indirect taxes has been enhanced by the reform. Accordingly, the curve for the combined tax system reveals a diminished redistributive effect. Once again, the overall test of the curve being equal to zero cannot be rejected. In this case, the non-rejection occurs at the three highest p-quantiles. The remaining part of the curve is found to be significantly different from zero.

In Decoster and Van Camp (2000b), we showed that the reranking measure defined here in footnote 20 was not significantly different from zero. Therefore, as far as inequality reduction is concerned, we tend to evaluate the PIT as well as the indirect tax reform, and consequently the joint tax reform, negatively. With a fixed distribution of pre-tax income, post-tax income is distributed more unequally than before the reform.

3. Dominance Results for TR*(p)*-Curves

As far as liability progression is concerned, the same line of reasoning can be followed to generalise the conclusions based on the Kakwani index. Figure 3a shows the *TR*(p)-curves for PIT, indirect taxes and the combined system before

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[33]See column 4 of Table A.2 in the Appendix.
[34]The critical values for a two-sided test with $\alpha = 0.05$ and five and six sub null hypotheses are 2.58 and 2.64 respectively. See Seber (1977, p. 131, Table 5.1).

FIGURE 3a

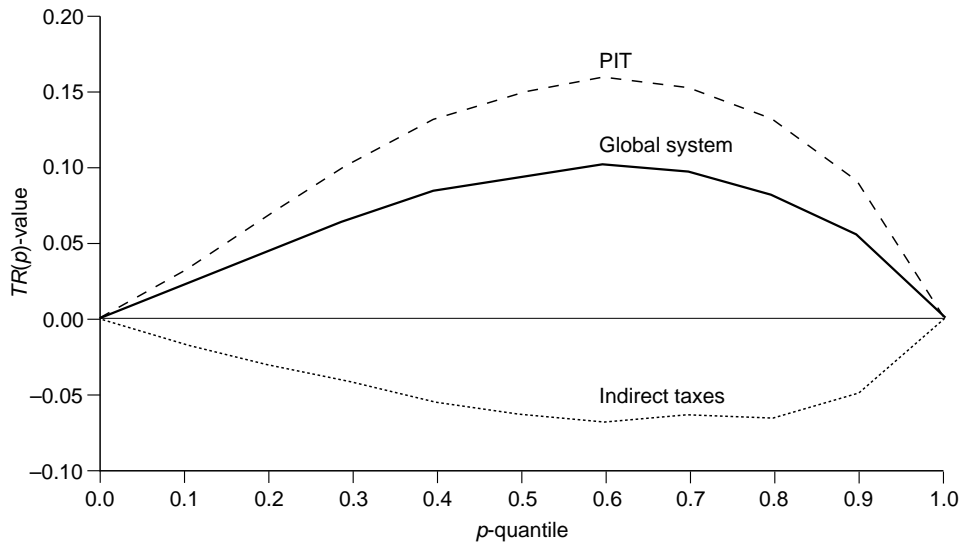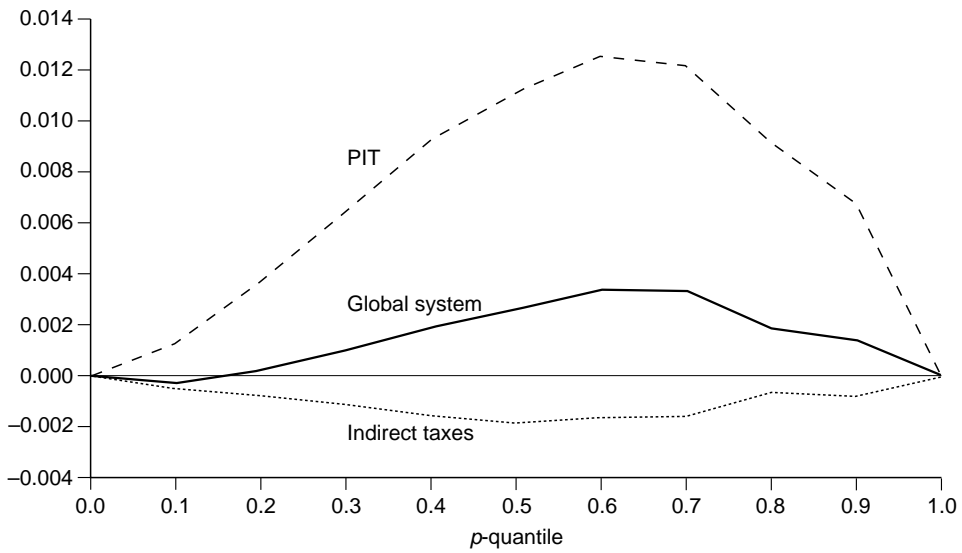**TR(*p*)-Values before the Reform**

FIGURE 3b

Change in *TR*(*p*)-Values due to the Reform

the reform.[35] Both before and after the reform (again, we do not show the post-reform curves), the curves are significantly different from zero. Hence, independently of the index used, the PIT system is progressive. At all income levels, part of the tax burden is shifted from bottom to top, when compared with a counterfactual proportional personal income tax. For indirect taxes, the reverse is the case. Lower deciles face higher tax liabilities than they would with proportional indirect taxes. Indirect taxes are regressive.

Figure 3b shows the change in $TR(p)$ caused by the reform. The $TR(p)$-curve after the PIT reform lies entirely above the one before the reform. The hypothesis that the before- and after-reform curves are similar is rejected. Therefore all liability progression measures will indicate a significant increase in the liability progression of the PIT system due to the reform. Also, the $TR(p)$-curve of the reformed indirect tax system is entirely dominated by the one before the reform. But these curves do not differ significantly from each other at each point. Non-rejections are observed for the two highest p-quantiles. However, the remaining parts of these curves differ from each other significantly.[36] Hence most indices would indicate a significant increase in the liability regressivity of the indirect tax system because of the reform.

Only for the combined system do we not find a dominance result as far as liability progression is concerned. For the bottom decile, the combined liability progression of PIT and indirect taxes decreases. This means that, after the reform, the bottom decile shifts a smaller share of the total tax burden to the top than it did before the reform. At all higher estimated points, liability progression increases. Hence only an index that gives a very high weight to the bottom decile can indicate that liability progressivity has gone down because of the tax reform.

But, again, we cannot reject at each point the hypothesis that the before- and after-reform curves are similar. Non-rejections are observed for the first two and the last two points. A similar null hypothesis of no change, applied on the part of the curve in between these rejected points, is rejected. Hence, after the reform, the ordinate estimates of the $TR(p)$-curve differ from each other significantly. Moreover, these ordinate $TR(p)$-values are always higher after the reform. Therefore, if these significance results are taken into account in the form of zero estimates at the rejected points, aggregate liability measures will indicate that the reform either has not changed the liability progression of the combined tax system or has increased it.

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[35]The numbers underlying Figures 3a and 3b can be found in Tables A.3 and A.4 of the Appendix.

[36]The critical value for a two-sided test with $\alpha = 0.05$ and seven sub null hypotheses is 2.69. See Seber (1977, p. 131, Table 5.1).

VI. CONCLUSION

We have evaluated the differences between the Belgian personal income tax and indirect tax systems of 1988 and 1993. Within this period, both the PIT system and the indirect tax system have been reformed considerably. The PIT reform was very much in line with what happened in other OECD countries. The tax base was broadened, top rates were reduced and the system moved away from joint taxation of married couples in the direction of individual taxation. The indirect tax reform discarded the rates of 17, 25 and 33 per cent and increased the 19 per cent rate to 19.5 per cent. Excises on fuels and tobacco products were increased. As a consequence, less revenue was collected via the PIT system, while indirect tax revenue increased. Since the cut in PIT was quantitatively more important than the increase in indirect taxes, overall revenue decreased.

To evaluate the joint impact of these reforms, the tax liabilities of both systems have been simulated on micro-datasets. For each tax system, we have compared the distribution of equivalised pre-tax income with the distributions of equivalised post-tax income and equivalised tax liabilities. These comparisons have been summarised both with indices and with Lorenz and concentration curves. We have applied recently developed statistical tools to test whether the indices and curves are significantly different from zero. Our conclusions are the following:

- The positive redistributive impact of the PIT system has been eroded by the tax reform. The negative redistributive impact of the indirect tax system has increased. For the joint tax system, this implies that the redistributive impact has also decreased.
- These conclusions about the change in the redistributive effect are fairly general. Estimates of the relevant Lorenz and concentration curves at nine points show that the systems before the reform always dominate those after the reform in terms of the redistributive impact.
- Not all before- and after-reform $IR(p)$-curves differ from each other significantly over the entire p-range, but they differ significantly over at least certain ranges of the distribution. Hence indices would, at best, indicate a *status quo* or else a reduction in the redistributive impact of the respective tax systems.
- The reduction in the redistributive effect of the combined tax system is mainly due to the negative impact of the reform of both PIT and indirect taxes at the bottom end of the distribution. With pre-tax income fixed, and given the change in average tax rates because of the reform, the bottom three deciles are the losers from the reform. The middle income classes are relatively unaffected. The top two deciles are the winners from the reform.
- The PIT reform has increased the liability progression of the PIT system. The liability regressivity of indirect taxes has been enhanced by the reform. Since

the PIT effect largely dominates the effect of indirect taxes, the liability progression of the combined tax system has also increased.

- Again, these conclusions are fairly general. In the case of PIT and indirect taxes, we obtain dominance results. For the combined tax system, there is no dominance. The liability progression decreases for the first decile but this effect is cancelled out by the increase in liability progression for all the other deciles. Yet the point at which the violation is observed is not estimated as significant. The before- and after-reform curves of each system differ significantly over a considerable range of the distribution.
- The reform has reduced the power of the combined tax system to narrow post-tax income inequality. Although this reduction is due to both a decrease of the positive redistributive effect of PIT and an increase of the negative redistributive effect of indirect taxes, it occurs for different reasons in each system. Since PIT has become more progressive, the decline in the redistributive effect is entirely due to the lower average tax rate. For indirect taxes, increasing liability regressivity and an increasing average tax rate work together to affect the inequality of post-tax incomes adversely.

It probably does not come as a surprise that indirect taxes became more regressive after the reform. The highest VAT rates were discarded and excises were increased. But the observations about the PIT reform are more intriguing. Despite the reduction of the top rates and the move in the direction of more individual taxation, liability progression increased. This issue can only be elucidated by proceeding through the different stages of the PIT process before and after the reform. In Decoster et al. (2000), we sketch the contributions made by deductions, tax rates and tax credits to the final redistribution of tax liabilities before and after the reform.

APPENDIX

TABLE A.1

Measure of Redistributive Effect before the Reform ($IR(p)$)-Curves of Figure 2a)

	Personal income taxes				Indirect taxes				Global taxes			
	$\hat{L}^B_{X:M}(p)$	$\hat{L}^B_{X:X}(p)$	$\hat{IR}^B(p)$		$\hat{L}^B_{X:M}(p)$	$\hat{L}^B_{X:X}(p)$	$\hat{IR}^B(p)$		$\hat{L}^B_{X:M}(p)$	$\hat{L}^B_{X:X}(p)$	$\hat{IR}^B(p)$	
p	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0.1	0.04660	0.03728	0.00933	*	0.03597	0.03728	-0.00131	*	0.04590	0.03728	0.00862	*
	(0.00078)	(0.00055)	(0.00035)		(0.00073)	(0.00055)	(0.00028)		(0.00083)	(0.00055)	(0.00041)	
0.2	0.10798	0.08816	0.01982	*	0.08571	0.08816	-0.00245	*	0.10691	0.08816	0.01875	*
	(0.00124)	(0.00109)	(0.00046)		(0.00118)	(0.00109)	(0.00021)		(0.00129)	(0.00109)	(0.00054)	
0.3	0.17915	0.14933	0.02983	*	0.14592	0.14933	-0.00341	*	0.17792	0.14933	0.02859	*
	(0.00169)	(0.00160)	(0.00070)		(0.00164)	(0.00160)	(0.00018)		(0.00177)	(0.00160)	(0.00079)	
0.4	0.25831	0.22016	0.03815	*	0.21568	0.22016	-0.00448	*	0.25656	0.22016	0.03640	*
	(0.00217)	(0.00210)	(0.00097)		(0.00214)	(0.00210)	(0.00023)		(0.00227)	(0.00210)	(0.00107)	
0.5	0.34312	0.30047	0.04264	*	0.29526	0.30047	-0.00521	*	0.34090	0.30047	0.04042	*
	(0.00261)	(0.00259)	(0.00124)		(0.00265)	(0.00259)	(0.00029)		(0.00273)	(0.00259)	(0.00136)	
0.6	0.43905	0.39304	0.04601	*	0.38741	0.39304	-0.00563	*	0.43664	0.39304	0.04360	*
	(0.00308)	(0.00305)	(0.00148)		(0.00315)	(0.00305)	(0.00032)		(0.00322)	(0.00305)	(0.00160)	
0.7	0.54383	0.50012	0.04372	*	0.49489	0.50012	-0.00522	*	0.54172	0.50012	0.04160	*
	(0.00347)	(0.00305)	(0.00171)		(0.00362)	(0.00347)	(0.00036)		(0.00366)	(0.00347)	(0.00183)	
0.8	0.66114	0.62342	0.03772	*	0.61796	0.62342	-0.00546	*	0.65806	0.62342	0.03464	*
	(0.00378)	(0.00376)	(0.00188)		(0.00398)	(0.00376)	(0.00043)		(0.00398)	(0.00376)	(0.00200)	
0.9	0.79929	0.77331	0.02598	*	0.76922	0.77331	-0.00409	*	0.79673	0.77331	0.02342	*
	(0.00384)	(0.00380)	(0.00189)		(0.00403)	(0.00380)	(0.00039)		(0.00407)	(0.00380)	(0.00199)	

Notes: Standard errors are given in parentheses.

The critical value $t^{\alpha/2;k}_{\infty}$ for $\alpha = 0.05$ and $k = 9$ is 2.78; see Seber (1977, p. 131, Table 5.1).

A * in column (4), (8) or (12) indicates that the sub null hypothesis of the value in respectively column (3), (7) or (11) not being equal to zero is rejected, given the critical value of 2.78.

TABLE A.2

Effect of the Reform on the Redistributive Effect (Figure 2b)

	Personal income taxes				Indirect taxes				Global taxes			
	$\hat{L}^A_{X;M}(p)$	$\hat{L}^B_{X;M}(p)$	$\hat{L}^A_{X;M}(p)$ $-\hat{L}^B_{X;M}(p)$		$\hat{L}^A_{X;M}(p)$	$\hat{L}^B_{X;M}(p)$	$\hat{L}^A_{X;M}(p)$ $-\hat{L}^B_{X;M}(p)$		$\hat{L}^A_{X;M}(p)$	$\hat{L}^B_{X;M}(p)$	$\hat{L}^A_{X;M}(p)$ $-\hat{L}^B_{X;M}(p)$	
p	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0.1	0.04614	0.04660	−0.00046		0.03585	0.03597	−0.00012	*	0.04530	0.04590	−0.00059	
	(0.00078)	(0.00078)	(0.00005)		(0.00074)	(0.00073)	(0.00001)		(0.00083)	(0.00083)	(0.00006)	
0.2	0.10726	0.10798	−0.00072		0.08551	0.08571	−0.00020	*	0.10598	0.10691	−0.00093	
	(0.00123)	(0.00124)	(0.00010)		(0.00119)	(0.00118)	(0.00001)		(0.00129)	(0.00129)	(0.00011)	
0.3	0.17827	0.17915	−0.00089		0.14564	0.14592	−0.00029	*	0.17676	0.17792	−0.00116	
	(0.00168)	(0.00169)	(0.00015)		(0.00165)	(0.00164)	(0.00002)		(0.00176)	(0.00177)	(0.00017)	
0.4	0.25744	0.25831	−0.00086		0.21529	0.21568	−0.00038	*	0.25536	0.25656	−0.00120	
	(0.00216)	(0.00217)	(0.00020)		(0.00214)	(0.00214)	(0.00002)		(0.00225)	(0.00227)	(0.00022)	
0.5	0.34234	0.34312	−0.00078		0.29481	0.29526	−0.00045	*	0.33974	0.34090	−0.00116	
	(0.00259)	(0.00261)	(0.00024)		(0.00265)	(0.00265)	(0.00003)		(0.00271)	(0.00273)	(0.00027)	
0.6	0.43835	0.43905	−0.00069	ns	0.38695	0.38741	−0.00045	*	0.43560	0.43664	−0.00104	
	(0.00306)	(0.00308)	(0.00029)		(0.00315)	(0.00315)	(0.00003)		(0.00320)	(0.00322)	(0.00032)	
0.7	0.54322	0.54383	−0.00061	ns	0.49446	0.49489	−0.00043	*	0.54078	0.54172	−0.00094	ns
	(0.00345)	(0.00347)	(0.00033)		(0.00363)	(0.00362)	(0.00003)		(0.00364)	(0.00366)	(0.00037)	
0.8	0.66026	0.66114	−0.00089	ns	0.61760	0.61796	−0.00036	*	0.65689	0.65806	−0.00117	ns
	(0.00375)	(0.00378)	(0.00037)		(0.00399)	(0.00398)	(0.00003)		(0.00396)	(0.00398)	(0.00041)	
0.9	0.79879	0.79929	−0.00050	ns	0.76892	0.76922	−0.00030	*	0.79599	0.79673	−0.00074	ns
	(0.00383)	(0.00384)	(0.00037)		(0.00404)	(0.00403)	(0.00003)		(0.00406)	(0.00407)	(0.00041)	

Notes: Standard errors are given in parentheses.

The critical value $t^{a/2;k}_{\infty}$ for $\alpha = 0.05$ and $k = 9$ is 2.78; see Seber (1977, p. 131, Table 5.1).

A * in column (4), (8) or (12) indicates that the sub null hypothesis of the value in respectively column (3), (7) or (11) not being equal to zero is rejected, given the critical value of 2.78. The label 'ns' denotes non-rejection of this sub null hypothesis.

TABLE A.3

Measure of Liability Progression before the Reform ($TR(p)$)-Curves of Figure 3a)

p	Personal income taxes $\hat{L}^B_{X:X}(p)$ (1)	$\hat{L}^B_{X:T}(p)$ (2)	$†R^B(p)$ (3)	(4)	Indirect taxes $\hat{L}^B_{X:X}(p)$ (5)	$\hat{L}^B_{X:T}(p)$ (6)	$†R^B(p)$ (7)	(8)	Global taxes $\hat{L}^B_{X:X}(p)$ (9)	$\hat{L}^B_{X:T}(p)$ (10)	$†R^B(p)$ (11)	(12)
0.1	0.03728	0.00540	0.03188	*	0.03728	0.05303	-0.01576	*	0.03728	0.01744	0.01984	*
	(0.00055)	(0.00077)	(0.00069)		(0.00055)	(0.00128)	(0.00121)		(0.00055)	(0.00076)	(0.00062)	
0.2	0.08816	0.02043	0.06774	*	0.08816	0.11776	-0.02960	*	0.08816	0.04503	0.04314	*
	(0.00109)	(0.00157)	(0.00136)		(0.00109)	(0.00197)	(0.00178)		(0.00109)	(0.00142)	(0.00107)	
0.3	0.14933	0.04740	0.10193	*	0.14933	0.19044	-0.04111	*	0.14933	0.08355	0.06578	*
	(0.00160)	(0.00246)	(0.00209)		(0.00160)	(0.00251)	(0.00228)		(0.00160)	(0.00214)	(0.00159)	
0.4	0.22016	0.08980	0.13036	*	0.22016	0.27424	-0.05408	*	0.22016	0.13641	0.08375	*
	(0.00210)	(0.00341)	(0.00278)		(0.00210)	(0.00309)	(0.00280)		(0.00210)	(0.00294)	(0.00210)	
0.5	0.30047	0.15473	0.14574	*	0.30047	0.36335	-0.06288	*	0.30047	0.20746	0.09301	*
	(0.00259)	(0.00455)	(0.00356)		(0.00259)	(0.00356)	(0.00327)		(0.00259)	(0.00385)	(0.00266)	
0.6	0.39304	0.23579	0.15724	*	0.39304	0.46095	-0.06792	*	0.39304	0.29270	0.10034	*
	(0.00305)	(0.00560)	(0.00434)		(0.00305)	(0.00399)	(0.00373)		(0.00305)	(0.00465)	(0.00321)	
0.7	0.50012	0.35071	0.14941	*	0.50012	0.56312	-0.06300	*	0.50012	0.40439	0.09572	*
	(0.00347)	(0.00669)	(0.00510)		(0.00347)	(0.00417)	(0.00410)		(0.00347)	(0.00546)	(0.00375)	
0.8	0.62342	0.49450	0.12892	*	0.62342	0.68923	-0.06582	*	0.62342	0.54372	0.07970	*
	(0.00376)	(0.00750)	(0.00565)		(0.00376)	(0.00425)	(0.00422)		(0.00376)	(0.00610)	(0.00417)	
0.9	0.77331	0.68451	0.08879	*	0.77331	0.82262	-0.04932	*	0.77331	0.71942	0.05389	*
	(0.00380)	(0.00784)	(0.00602)		(0.00380)	(0.00408)	(0.00431)		(0.00380)	(0.00618)	(0.00433)	

Notes: Standard errors are given in parentheses.

The critical value $t^{\alpha/2;k}_{\infty}$ for $\alpha = 0.05$ and $k = 9$ is 2.78; see Seber (1977, p. 131, Table 5.1).

A * in column (4), (8) or (12) indicates that the sub null hypothesis of the value in respectively column (3), (7) or (11) not being equal to zero is rejected, given the critical value of 2.78.

TABLE A.4

Effect of the Reform on the Liability Progression (Figure 3b)

	Personal income taxes				Indirect taxes				Global taxes			
	$\hat{L}^B_{X;T}(p)$	$\hat{L}^A_{X;T}(p)$	$\hat{L}^B_{X;T}(p)$ $-\hat{L}^A_{X;T}(p)$		$\hat{L}^B_{X;T}(p)$	$\hat{L}^A_{X;T}(p)$	$\hat{L}^B_{X;T}(p)$ $-\hat{L}^A_{X;T}(p)$		$\hat{L}^B_{X;T}(p)$	$\hat{L}^A_{X;T}(p)$	$\hat{L}^B_{X;T}(p)$ $-\hat{L}^A_{X;T}(p)$	
p	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0.1	0.00540 (0.00077)	0.00406 (0.00071)	0.00133 (0.00015)	*	0.05303 (0.00128)	0.05354 (0.00126)	−0.00051 (0.00011)		0.01744 (0.00076)	0.01773 (0.00073)	−0.00029 (0.00012)	ns
0.2	0.02043 (0.00157)	0.01665 (0.00152)	0.00377 (0.00027)	*	0.11776 (0.00197)	0.11853 (0.00192)	−0.00077 (0.00018)		0.04503 (0.00142)	0.04479 (0.00138)	0.00024 (0.00021)	ns
0.3	0.04740 (0.00246)	0.04096 (0.00242)	0.00644 (0.00041)	*	0.19044 (0.00251)	0.19157 (0.00244)	−0.00113 (0.00025)		0.08355 (0.00214)	0.08255 (0.00209)	0.00100 (0.00031)	
0.4	0.08980 (0.00341)	0.08055 (0.00340)	0.00925 (0.00055)	*	0.27424 (0.00309)	0.27583 (0.00300)	−0.00159 (0.00031)		0.13641 (0.00294)	0.13448 (0.00290)	0.00193 (0.00042)	
0.5	0.15473 (0.00455)	0.14371 (0.00460)	0.01102 (0.00067)	*	0.36335 (0.00356)	0.36521 (0.00343)	−0.00186 (0.00037)		0.20746 (0.00385)	0.20488 (0.00382)	0.00258 (0.00050)	
0.6	0.23579 (0.00560)	0.22334 (0.00568)	0.01246 (0.00079)	*	0.46095 (0.00399)	0.46263 (0.00382)	−0.00168 (0.00042)		0.29270 (0.00465)	0.28942 (0.00461)	0.00328 (0.00060)	
0.7	0.35071 (0.00669)	0.33869 (0.00682)	0.01202 (0.00094)	*	0.56312 (0.00417)	0.56476 (0.00398)	−0.00164 (0.00046)		0.40439 (0.00546)	0.40112 (0.00542)	0.00327 (0.00071)	
0.8	0.49450 (0.00750)	0.48547 (0.00763)	0.00903 (0.00109)	*	0.68923 (0.00425)	0.68993 (0.00406)	−0.00069 (0.00046)	ns	0.54372 (0.00610)	0.54194 (0.00606)	0.00178 (0.00083)	ns
0.9	0.68451 (0.00784)	0.67788 (0.00791)	0.00664 (0.00114)	*	0.82262 (0.00408)	0.82352 (0.00390)	−0.00089 (0.00044)	ns	0.71942 (0.00618)	0.71809 (0.00608)	0.00132 (0.00086)	ns

Notes: Standard errors are given in parentheses.

The critical value $t^{\alpha/2k}_{\infty}$ for $\alpha = 0.05$ and $k = 9$ is 2.78; see Seber (1977, p. 131, Table 5.1).

A * in column (4), (8) or (12) indicates that the sub null hypothesis of the value in respectively column (3), (7) or (11) not being equal to zero is rejected, given the critical value of 2.78. The label 'ns' denotes non-rejection of this sub null hypothesis.

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