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Policy evaluation in a non-welfarist framework

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De plek

Je moet niet alleen, om de plek te bereiken,

thuis opstappen, maar ook uit manieren van kijken.

Er is niets te zien, en dat moet je zien,

om alles bij het zeer oude te laten.

Er is hier. Er is tijd

om overmorgen iets te hebben achtergelaten.

Daar moet je vandaag voor zorgen.

Voor sterfelijkheid.

Herman de Coninck

voor Fien en Yle

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Chapter 1

Framework and outline

1.1 Observing preferences

Policymakers face the challenge of taking policy decisions with the aim to improve social welfare in the economy. These policy decisions should be based on sound indicators of social welfare. There is a general consensus that policymakers should respect the households' judgments about their own lives (Fleurbaey and Blanchet (2013)). These individual judgments can be understood as the households' 'true underlying preferences' (Qizilbash (2012)). One problem is that information on true underlying preferences is not easy to obtain. In practice, one can only obtain information by observing preferences, either by relying on revealed or stated preference approaches, or by relying on survey data –e.g. based on self-reported life satisfaction. But what if these observed preferences are not a reflection of the individuals' true underlying preferences?

In (welfare) economics, true underlying preferences are assumed to be stable, consistent and context-independent, and rational and perfectly informed households seek to satisfy these preferences (McQuillin and Sugden (2012)). If these conventional assumptions are valid, then observed preferences reflect individuals' true underlying preferences. There is compelling evidence, however, that observed preferences can be flawed. Due to human limitations, an indivividual's behaviour is not consistent with his true underlying preferences (Qizilbash (2012)). In this case, the idea of consumer sovereignty is false. Three broad types of anomalies can be distinguished in this respect.

In the first type, households might be well-informed, but they do not act rationally, i.e. they do not choose the best option given their true underlying preferences. This problem pertains to time inconsistent behaviour, households take decisions today, but without fully considering their future. They engage in unhealthy lifestyles (e.g. smoking, not doing sports, eating fat foods) or save insufficiently for their pension. Households might know the long-run consequences of their behaviour, but postpone behavioural change because they have the tendency to seek immediate gratification. They take repeated decisions with small time intervals and the consequence of each decision is small, remote in time and still avoidable today (Akerlof (1991)). In this case, the households' true underlying preferences are not revealed by their market behaviour.

Policymakers are aware of this and aim to discourage, restrict or even forbid certain behaviours or commodities. Goods the policymaker values higher (lower) than the households are called (de)merit goods. High taxes on cigarettes and smoking bans in public places or subsidies for sports clubs can be rationalized in this way. Policymakers nudge the households in a specific direction so that they act according to their true underlying preferences. The general idea behind this type of policy is that the policymaker aims to increase welfare, even if it is against the households' observed preferences.

The second anomaly is due to a lack of information when individuals judge about their preferences, also if they behave rationally. In some cases, individuals are badly positioned to cast a judgment. For instance when individuals lack experience, their observed behaviour might reflect his lack of information rather than his true preferences. Take the example of a student who has to judge about the content or the quality of a course he has taken. As he does not yet know how the information provided in the course could serve him in the future, his judgment will not reflect his true underlying preferences as he does not know them.

The third type of anomaly has to do with a situation in which individuals might be rational and well-informed, but their observed preferences are not stable, not consistent or context independent. Then people fail when judging decisions or their life situation because their judgment is distorted. Many examples are provided in the literature. Individuals have the tendency to over-weight low probabilities (McQuillin and Sugden (2012)), they are bad in predicting future feelings and underestimate how easily they can adapt to changes in their situation (Fleurbaey and Blanchet (2013)), or focus too much on small details while forgetting the bigger picture. For this reason, they badly organize activities, lose time or stick too often with the status quo (Qizilbash (2012)). Observed preferences might also depend on the context in which the individual finds himself, or on the framing of the choice problem. When asked to judge about their situation, they might give too much weight to their current mood or their aspirations (see Fleurbaey and Blanchet (2013)). As a consequence, information on individuals' true underlying preferences is hard to obtain.

Observed preferences differ from true underlying preferences in these cases. The conventional assumptions stated above are then based on an unrealistic view on the nature of human beings. The policymaker should not base policy on observed preferences, but needs to correct in some way. In this situation, the policymaker is said to act as a paternalist. This dissertation deals with instances in which households' observed preferences are mistaken and focuses on solutions for policymakers. The second chapter deals with policy when households are not rational or well-informed. Chapters 3 and 4 focus on welfare measurement.

1.2 Lack of rationality

Chapter 2 deals with indirect tax policy in the case where households' revealed preferences fall short of their true underlying preferences. Marginal costs of funds (MCF) are calculated for taxes on 13 commodities in Belgium, the consumption of which creates an environmental externality in the form of carbon dioxide emissions. The MCF of an indirect tax measures the impact on social welfare of an increase of that tax rate. Social welfare is the (weighted) sum of the utility levels of all households in the economy. Social welfare can be increased in a revenue neutral way if the MCF differ numerically.

If observed preferences are to be respected, the MCF expressions contain two parts. The first one is due to the impact of the tax increase on household utilities via their own consumption levels. It has been proposed by Ahmad and Stern (1984). The impact of an indirect tax increase is measured based on the budgets households spend on the taxed commodity. If a commodity is consumed more, its MCF is higher. The second part is due to the impact of the tax increase on carbon dioxide emissions, which influences the utilities of all households. The externality part has been analysed by Schöb (1996) and Mayeres and Proost (2001) and measures the impact on household utilities due to the fact that they suffer from the emissions, ideally based on their willingness to pay for a decrease in emissions. A commodity with high carbon dioxide emissions has a lower MCF.

The problem is that households are unaware of the consequences of their emissions of carbon dioxide, as they only appear in the long run. Their willingness to pay for a decrease in carbon dioxide emissions is too low and thus the externality has demerit properties. Even if households were well informed, they might postpone their efforts to cut down their emissions. Consequently, their consumption behaviour does not reflect their true underlying preferences and this is an argument for the policymaker to intervene. In the chapter, the consequence of this idea are investigated for the MCF expressions. The work is an extention of Schroyen (2010), who investigated the consequences of a private demerit good for the MCF expressions. The incorporation of the demerit externality implies three extra terms in the MCF expression, a direct effect, a scale effect and an income effect. The direct effect takes into account the fact that the externality is valued higher. The scale effect takes into account the fact that, due to demerit arguments, households are considered worse off than they think they are, and as a consequence their valuations of all commodities need to be adapted. The income effect is due to the fact that household utility counts relatively less from the point of view of the policymaker, as the externality is not valued sufficiently. The empirical findings for Belgium suggest that a revenue neutral tax reform can be achieved by increasing the indirect taxes on electricity, meat & fish, gas and fuels for heating, and decreasing the indirect taxes on clothing & shoes, durables, food & beverages.

1.3 Welfare measurement

Chapter 3 and 4 deal with measurement of respectively job quality and well-being. Job quality and well-being are essentially multidimensional concepts. In some cases it is necessary to calculate a one-dimensional measure, such that weights need to be attached to the different dimensions. There are two attractive principles such a measure can satisfy: respect for preferences and dominance. Respect for preferences means that the weights are determined based on preferences. Then the policymaker respects the trade-offs individuals make between the dimensions. The domininance principle means that the one-dimenional measure increases in all underlying dimensions. Fleurbaey et al. (2009) argue that, as it is impossible to satisfy both principles at the same time, a choice has to be made for one of the two. Either the dominance principle or the respect for preferences principle has to be sacrificed.

1.3.1 Lack of information

Chapter 3 deals with job quality measurement for 2310 individuals who entered the labour market in Flanders. A job is described in terms of the achievement of five job characteristics: income, the extent to which the job is physically demanding, skill utilization, work endeavour and autonomy. Individuals in their first job might behave rationally, but they might be ill-informed to judge about the quality of their jobs. For this reason, their observed preferences might not reflect their true underlying preferences. It is argued in the chapter that in this case, one should use a job quality measure satisfying dominance, and sacrifice the respect for preferences principle. The output distance function is used to measure job quality. It is a concept commonly used to analyse firm efficiency. Lovell et al. (1994) have proposed to use the distance function as a measure of well-being. The achieved bundle is compared to a specific maximal attainable bundle of job characteristics, consequently, job quality is measured as a percentage. Evidently, this measure satisfies the dominance principle.

The aim of the chapter is to use the calculated job qualities to measure inequality of opportunity at job market entry. To do this, job quality is related to two types of personal characteristics: circumstances and efforts. Circumstances are personal characteristics he is not held responsible for, such as his gender or the education level of his parents. Efforts are characteristics the individual is held responsible for, for instance his own education level. Inequality of opportunity is measured as the percentage inequality would be reduced if all individuals had the same circumstances. The difference between these two can only be due to unequal opportunities. The results suggest that around 13% of observed inequality is due to inequality of circumstances, whereas income inequality would be reduced with 4-8% if all circumstances had been equal.

1.3.2 Affects and cognition

The fourth chapter in this dissertation deals with obtaining information on true underlying preferences from survey data, necessary for the calculation of equivalent income. An individual's life is described as the achievement of a number of functionings, such as health or material living standards. Equivalent income is the level of income that, given reference values for the other dimensions of functionings, makes an individual indifferent to his actual situation. This concept has been proposed by Fleurbaey et al. (2009), it respects preferences, but does not satisfy the dominance criterion.

The dimensions of functionings dealt with in the chapter are based on Stiglitz et al. (2009): income, health, education, personal activities including work, social connections and relationships and living environment. Information on preferences for dimensions of functionings is usually derived from the answers individuals provide to one or more overarching life evaluation questions. A common approach in the literature is to ask people to evaluate their life satisfaction on a scale from zero to ten. In the survey used in the chapter, the question goes as follows: "How satisfied are you with your life as a whole, on a scale from 0 (completely insufficient) to 10 (excellent)". There are two basic problems concerning the use of raw data on life satisfaction.

The first problem is related to the physical condition neglect of satisfaction information (Sen (1980 and 1985)): the mental state of the individual does not say anything per se about his physical condition. People may adapt their aspirations to their life situation and state to be relatively satisfied when they are income poor or in bad health. The second problem has to do with the fact that the answers people provide to the self-reported satisfaction question are a mixture of two things: a cognitive judgment –what people think of their life– and an affective judgment –how people feel in their life (Fleurbaey and Blanchet (2013)). Information on true underlying preferences should be based on the former, not on the latter, as affective information might be influenced by moods –which are typically short-lived.

Consequently, in order to get information on the cognitive evaluation of the individuals, which provide information on their true underlying preferences, the effects of aspirations and affects have to be filtered. The equivalent income approach does this, on the condition that what remains after filtering is cognitive information on the individual's life. Fleurbaey et al. (2009) assume that aspirations depend on individual characteristics such as the individuals' age or gender.

If another overarching life evaluation question can be found that depends less on affects and aspirations, it might provide a less biased picture on the individuals' true underlying preferences, as no correction for affects and aspirations is needed. McQuillin and Sugden (2012) argue that it could be interesting to identify another object of value, assign normative value to it, and try to measure it to obtain information on preferences. In the chapter it is investigated whether the concept of self-reported possibilities, which measures the extent to which individuals have the ability to strive for whatever they want, provides more reliable information. The question goes as follows: "How are the possibilities for you, in general, on a scale from 0 (completely insufficient) to 10 (excellent)". It is shown that the answers to this question are less sensitive for the individuals' mood of the day or their aspirations. As such, they might come closer to a cognitive evaluation of the individuals' lives. Self reported possibilities could provide less biased information on true underlying preferences than self-reported life satisfaction.

The survey contains, apart from information on individual characterstics, also information on the individuals' personality and their mood of the day. The approach of Fleurbaey et al. (2009) is followed. Direct effects of these variables are assumed to reflect differences in aspirations and affects, the interactions of these variables with the functionings dimensions are assumed to provide information on the individuals' true preferences. Equivalent income is calculated based on life satisfaction and possibilities and compared with income and the answers people provide on the life satisfaction and possibilities questions.

The two equivalent income measures are very similar, their correlation is around 90%. This suggests that both concepts provide information on the individuals' true underlying preferences. It is argued that, as self-reported possibilities are less sensitive for adaptive preferences, they are less biased than self-reported satisfaction. It is shown that the correlations between the equivalent income measures and observed income are rather low. Consequently, income falls short as a measure to determine who is to be considered poor. Both self-reported satisfaction and self-reported possibilities correlate highly with the equivalent income measures, though the correlations with self-reported possibilities are higher.

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Chapter 2

Marginal Cost of Indirect Taxation in the presence of a Demerit Externality: Application to CO_2 emissions

2.1 Introduction

This paper deals with indirect tax policy design when there is an externality (CO_2) related with energy use that is undervalued by consumers. Because consumers focus too much on the present, the (long run) consequences of CO_2 are insufficiently taken into account when they decide upon consumption today. The households suffer some negative effects of the externality, but not all of the effects. The planner (i.e. the government) knows this and aims at correcting this problem by altering indirect tax rates. In the economic jargon, CO_2 is seen as a demerit good.

The analysis is performed using the concept of the marginal cost of funds (MCF) of indirect taxation. This is the social welfare cost of raising one euro of tax money by increasing a specific indirect tax rate. The literature in this field originated from the seminal paper of Ahmad and Stern (1984). In that contribution, only private commodities were considered. Externalities were taken into account in subsequent studies, e.g. Schöb (1996) or Mayeres and Proost (2001) who considered the effects on pollution and traffic congestion. In all of this literature, the planner endorses consumer sovereignty. Public and private goods are only valuable for society to the extent that households value them, based on observed behaviour. Private goods are valued using the market price, public goods are valued using the sum of the willingness to pay of all households.

In some cases, however, households' 'true' preferences may not be revealed by their behaviour and governments do not accept consumer sovereignty. This applies to carbon dioxide emissions as well. The chosen consumption bundle is not the one consumers truly prefer when the consequences of CO_2 are not fully taken into account in their decisions. Take the example of transport. Workers choose between their bike and their car to go to work, say for a short distance. They know that the choice for the latter causes more carbon dioxide emissions than the choice for the former, but this only plays a minor role in their decision-making process. As a consequence, they choose to use their car too often. The consequences for carbon dioxide emissions are not taken into account sufficiently, although when asked about it, individuals acknowledge that these consequences are real and important. They may intend to change their behaviour - tomorrow. They are aware of the fact that long run costs of emitting CO_2 exceed the benefits, but they

[0]I would like to thank Dirk Van de gaer for constructive comments on preliminary versions of this paper and Brent Bleys and An-Sofie Cottyn, two of my colleagues, for making linguistic suggestions and corrections.

procrastinate to change their behaviour because they have a tendency to seek immediate gratification. Short run costs and benefits have undue salience over long run costs and benefits (see Akerlof (1991), O'Donoghue and Rabin (2001)).

An important feature of this type of behaviour is that individuals take repeated decisions (e.g. to use the car to go to work) with small time intervals and that the consequences of each decision are small, remote in time and still avoidable today (Akerlof, 1991). Because of this, the households' 'true' preferences are not revealed by market behaviour. The assumption of rational, forward looking, utility maximizing households is violated and there is a reason for the planner to intervene. Governments aim to discourage, restrict or even forbid the consumption of demerit goods[1] like tobacco because they want to protect individuals against illness at old age. In a number of recent contributions (Schroyen, 2005 and 2010), MCF expressions for indirect taxes have been derived for an economy in which there is a private commodity with demerit properties (e.g. cigarettes, hard drugs...).

In this paper, Schroyen's model is extended to include an externality with demerit properties. The model is applied to CO_2 emissions as demerit externality. Apart from the externality correction, the planner has to correct the MCF for demerit considerations as well. There is an important distinction between these two. If the externality problem is solved, on average the households gain (today). This does not hold for the demerit problem, because from the households' point of view, the planner corrects too much. As such, this paper is about applied paternalism. The planner acts against the short-run interest of the households today because he believes their short-run preferences are mistaken.

Based on observed behaviour the valuation of one tonne of CO_2 is too low, energy intensive commodities are valued too highly. The planner knows this and aims at changing relative prices in order to make sure households change their behaviour today. He wants to influence current consumption decisions by putting a higher value on a tonne of carbon dioxide, i.e. by considering it as a demerit good, such that a commodity that has a higher impact on CO_2 is valued lower. This is the 'direct' correction for demerit considerations that will be derived in this paper. Apart from this first result, there are two other results

[1]The term (de)merit good is due to Musgrave (1959). According to him, merit and demerit goods are goods for which the preference of the planner differs from the preference of the households. The planner attributes a higher value than the household(s) to merit goods and a lower value to demerit goods. Other demerit arguments in the literature are uncertainty, irrational preferences and information deficiency (e.g. myopia, ignorance).

in the derivation below that are somewhat less intuitive. The second correction is a valuation effect due to an income effect. Because the households suffer more from the externality than they are aware of, the planner evaluates them as if they are on a lower utility level. As a consequence, the households' valuations for all commodities change, as households' willingness to pay for commodities depends on how well-off they are. The third correction has to do with the fact the planner takes into account an externality effect that was not sufficiently taken into account before. As a consequence, household utility counts relatively less. Only a specific percentage of the households' commodity valuations is considered valuable from a social point of view. These are the three consequences of the demerit considerations for the MCF that are derived below. In the empirical section, the MCF of indirect taxes on 13 commodities are calculated for Belgium.

In the next section, it is shown formally how the planner's valuation of a commodity differs from the household's valuation. Then the MCF of indirect taxation are derived. The third section applies the framework to Belgian indirect taxes in the presence of carbon dioxide emissions. The fourth section concludes.

2.2 The model

2.2.1 Notation and household behaviour

Assume there are n households, M commodities and an externality (E) in the economy. Household h's consumption of commodity j is $x_j^h \in \mathbb{R}_+$ and his expenditurs are $m^h \in \mathbb{R}_+$. It consumes a commodity vector $x^h \in \mathbb{R}_+^M$, $x^h = [x_1^h, ..., x_M^h]$. The vector collecting the consumption of commodity j is $x_j \in \mathbb{R}_+^n$, $x_j = [x_j^1, ..., x_j^n]$. Finally, $x \in \mathbb{R}_+^{Mn}$ is the $M \times n$ dimensional matrix of commodity consumption by all households. The externality E is created by total household consumption of commodities: $E(x) : \mathbb{R}_+^{Mn} \to \mathbb{R}_+$. Household h has a quasi-concave utility function $u^h\left(x^h; E\right) : \mathbb{R}_+^M \times \mathbb{R}_+ \to \mathbb{R}$ increasing in all x_j^h and decreasing in E. The after tax price of commodity j is q_j and p_j is the pre tax price of commodity j, which is assumed to be fixed for all j. The indirect tax on commodity j is t_j, so $q_j = p_j + t_j$ ($q_j, p_j \in \mathbb{R}_+$ and $t_j \in \mathbb{R}$). The vector $q = [q_1, ..., q_M]$ is the vector of commodity prices. Household h's Marshallian demand for commodity j is $x_j^h\left(q, m^h; E\right)$. The household's marginal utility of (one euro of) income is $\alpha^h \in \mathbb{R}_+$.

Each household h solves the following problem

$$\text{Max } u^h\left(x^h; E\right) \text{ s.t. } \sum_{j=1}^{M} q_j x_j^h = m^h. \tag{1}$$

It decides upon the amount of private commodities it consumes, taking into account the impact of its decisions on E. The first order conditions can be written as

$$q_j = \frac{\frac{\partial u^h\left(x^h;E\right)}{\partial x_j^h} + \frac{\partial u^h\left(x^h;E\right)}{\partial E}\frac{\partial E}{\partial x_j^h}}{\alpha^h}, \text{ for all } j = 1, ..., M.$$

The right hand side of this expression measures household h's willingness to pay for a unit of commodity j, it is the household's valuation of x_j^h in the optimum. Call it $q_j^h\left(x^h; E\right)$:

$$q_j^h\left(x^h; E\right) \equiv \frac{\frac{\partial u^h\left(x^h;E\right)}{\partial x_j^h} + \frac{\partial u^h\left(x^h;E\right)}{\partial E}\frac{\partial E}{\partial x_j^h}}{\alpha^h}, \text{ for all } j = 1, ..., M. \tag{2}$$

The numerator is the household's marginal utility of consumption of commodity i. Note that the household takes into account the impact of its consumption of x_j^h on E on its own utility only, not the impact on others.

For future reference, define

$$q_E^h\left(x^h; E\right) \equiv \frac{\frac{\partial u^h\left(x^h;E\right)}{\partial E}}{\alpha^h}, \text{ for all } h, \tag{3}$$

household h's marginal willingness to pay for a unit of the externality. As the numerator is negative, $q_E^h\left(x^h; E\right) < 0$.

2.2.2 The planner

The planner does not agree with the households' valuations of commodities and E for two reasons: the existence of an externality and the existence of demerit arguments. First we deal with the externality. The planner aims to maximise social welfare, not just individual h's welfare. Assume that the planner has the following objective function:

$$W(x;E)=\sum_{h=1}^{n}\lambda^{h}u^{h}\left(x^{h};E\right).$$

To the extent that one household's behaviour influences other households' utilities, adjustments are needed. This is the standard externality correction (see e.g. Pigou (1947) or Cornes and Sandler (1996)). If household h consumes an extra unit of commodity j, the impact on social welfare is

$$\frac{\partial W(x;E)}{\partial x_{j}^{h}}=\lambda^{h}\left(\frac{\partial u^{h}\left(x^{h};E\right)}{\partial x_{j}^{h}}+\frac{\partial u^{h}\left(x^{h};E\right)}{\partial E}\frac{\partial E}{\partial x_{j}^{h}}\right)+\sum_{\substack{l=1\\ l\neq h}}^{n}\lambda^{l}\frac{\partial u^{l}\left(x^{l};E\right)}{\partial E}\frac{\partial E}{\partial x_{j}^{h}}.$$

Demerit arguments are not yet included. This brings us with the second correction the planner performs. Household welfare is not perceived in the same way by the government as by the household due to demerit arguments. To incorporate this, assume the planner evaluates household h's situation with another utility function:

$$\widetilde{u}\left(x^{h};E\right). \tag{4}$$

This function is such that $\widetilde{u}\left(x^{h};E\right):\mathbb{R}_{+}^{M}\times\mathbb{R}_{+}\rightarrow\mathbb{R}$. It will be used in the social welfare function instead of $u^{h}\left(x^{h};E\right)$. We impose a formal relationship between $\widetilde{u}\left(x^{h};E\right)$ and $u^{h}\left(x^{h};E\right)$. One approach to take into account demerit arguments has been formalised by Schroyen (see Schroyen (2005) and Schroyen (2010)), for a private (de)merit good. He proposes a scaling approach to commodity consumption. He uses the distance function $d^{h}\left(x^{h},\overline{u^{h}};E\right):\mathbb{R}_{+}^{M}\times\mathbb{R}\times\mathbb{R}_{+}\rightarrow\mathbb{R}_{+}$ (see Deaton and Muellbauer (1980)), which is implicitly defined by

$$u^{h}\left(\frac{x^{h}}{d^{h}\left(x^{h},\overline{u^{h}};E\right)};\frac{E}{d^{h}\left(x^{h},\overline{u^{h}};E\right)}\right)=\overline{u^{h}}. \tag{5}$$

The distance $d^{h}\left(x^{h},\overline{u^{h}};E\right)$ is the amount by which private consumption and E need to be scaled to reach a reference utility level $\overline{u^{h}}$. If x^{h} and E happen to be on the indifference curve corresponding to $\overline{u^{h}}$, $d^{h}\left(x^{h},\overline{u^{h}};E\right)=1$. The planner disagrees with the amount $d^{h}\left(x^{h},\overline{u^{h}};E\right)$ because of demerit arguments. He believes that, in order to reach the reference utility level, commodity consumption and

E need to be scaled by a different amount $d^{ph}\left(x^h, \overline{u^h}; E\right) : \mathbb{R}_+^M \times \mathbb{R} \times \mathbb{R}_+ \to \mathbb{R}_+$. As in Schroyen (2010), we assume that the planner uses the following formal relationship between $d^h\left(x^h, \overline{u^h}; E\right)$ and $d^{ph}\left(x^h, \overline{u^h}; E\right)$:

$$d^{ph}\left(x^h, \overline{u^h}; E\right) = d^h\left(x^h, \overline{u^h}; E\right) + eE, \tag{6}$$

with $e < 0$ a public demerit parameter for the externality with the dimension of a normalised price (a price relative to income). It measures how much the household should value one unit of externality E as a percentage of income, on top of its private valuation. It is shown in appendix D that the formal relationship between $\widetilde{u}\left(x^h; E\right)$ and $u^h\left(x^h; E\right)$ is

$$\begin{aligned} \widetilde{u}\left(x^h; E\right) &= u^h\left(\frac{x^h}{1-eE}; \frac{E}{1-eE}\right) \\ &= u^h\left(\widehat{x}^h; \widehat{E}\right) \\ \text{with } \widehat{x}^h &= \frac{x^h}{1-eE} \text{ and } \widehat{E} = \frac{E}{1-eE}. \end{aligned} \tag{7}$$

This is the counterpart of expression (8) in Schroyen (2010) on page 46. The planner evaluates the household at a different (lower) utility level because there are demerit arguments which the household does not take into account.[2] The planner's objective changes into

$$\begin{aligned} W(x; E) &= \sum_{h=1}^{n} \lambda^h \widetilde{u}\left(x^h; E\right) \\ &= \sum_{h=1}^{n} \lambda^h u^h\left(\widehat{x}^h; \widehat{E}\right). \end{aligned}$$

This expression has two relevant aspects, for our purposes. First of all, it is suited to take into account the externality: each household's behaviour influences other households' utilities. Secondly, due to demerit

[2]Expression (2), household h's willingness to pay for a unit of commodity j, could now be written from the point of view of the planner. Making use of expression A7 in appendix A: $\frac{1}{\alpha^h}\left[\left(\frac{\partial u^h\left(\widehat{x}^h;\widehat{E}\right)}{\partial \widehat{x}_j^h} + \frac{\partial u^h\left(\widehat{x}^h;\widehat{E}\right)}{\partial \widehat{E}}\frac{\partial E}{\partial x_j^h}\right)\frac{1}{1-eE} + \left(\sum_{l=1}^{M}\frac{\partial u^h\left(\widehat{x}^h;\widehat{E}\right)}{\partial \widehat{x}_l^h}x_l^h + \frac{\partial u^h\left(\widehat{x}^h;\widehat{E}\right)}{\partial \widehat{E}}E\right)\frac{e}{(1-eE)^2}\frac{\partial E}{\partial x_j^h}\right]$.

In the appendix, this expression is used to derive the marginal cost of funds expressions by taking into account not only the effect on household h's utility, but the effect on all other households' utilities.

arguments, the households' 'adapted' utilities are used instead of their 'experienced' utilities. In appendix A, these two aspects are distinguished. The complication of the model is the fact that each household's behaviour implies an effect on each of the other households' adapted utilities in a non-trivial way.

2.2.3 Marginal cost of funds derivation

Now we are ready to derive the marginal cost of funds expressions. The planner decides about indirect tax rates t and has a revenue constraint $R(t)$. The planner's aim is to maximise social welfare such that the revenue constraint is satisfied, he maximises

$$W(t) = \sum_{h=1}^{n} \lambda^h u^h \left(\widehat{x}^h(t); \widehat{E} \right) \tag{8}$$

such that

$$R(t) = \overline{R} + \sum_{i=1}^{M} \sum_{h=1}^{n} t_i x_i^h \tag{9}$$

with $\overline{R}$ exogenous revenue. The marginal cost of funds of the tax on commodity i is

$$MCF_i = -\frac{\frac{\partial W(t)}{\partial t_i}}{\frac{\partial R(t)}{\partial t_i}}. \tag{10}$$

It measures the marginal impact on social welfare of raising additional revenue by increasing the tax on commodity i. If the marginal cost of funds of two commodities differs, say for commodities $MCF_i > MCF_j$, then a budget neutral welfare improving tax reform can be realized by increasing the tax on commodity j and decreasing the tax on commodity i.

First we calculate $\frac{\partial R}{\partial t_i}$. We assume horizontal supply curves, resulting in fixed producer prices; $\frac{\partial x_j^h}{\partial t_i} = \frac{\partial x_j^h}{\partial q_i}$ for all i, j, h.

$$\frac{\partial R(t)}{\partial t_i} = \sum_{h=1}^{n} x_i^h + \sum_{j=1}^{M} \sum_{h=1}^{n} t_j \frac{\partial x_j^h}{\partial q_i}.$$

Now we multiply with q_i and transform derivates into elasticities to obtain the following standard expression:

$$\frac{\partial R(t)}{\partial t_i}q_i = \sum_{h=1}^{n} x_i^h q_i + \sum_{j=1}^{M}\sum_{h=1}^{n}\frac{t_j}{q_j}q_j x_j^h \varepsilon_{ji}^h, \tag{11}$$

$$\text{where } \varepsilon_{ji}^h = \frac{\partial x_j^h}{\partial q_i}\frac{q_i}{x_j^h}.$$

The numerator of the marginal cost of funds formula, multiplied by q_i is

$$\frac{\partial W(t)}{\partial t_i}q_i = \sum_{h=1}^{n}\frac{\partial u^h\left(\widehat{x}^h(t);\widehat{E}\right)}{\partial t_i}q_i.$$

The expression for $\frac{\partial W(t)}{\partial t_i}$ is derived in appendix A as expression (A22), here repeated for convenience:

$$\begin{aligned}\frac{\partial W(t)}{\partial t_i} &= \sum_{l=1}^{n}\Lambda^l\left[\sum_{j=1}^{M} q_j\frac{\partial x_j^l}{\partial q_i} + q_E^l\sum_{\substack{h=1\\h\neq l}}^{n}\sum_{j=1}^{M}\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\right](1+eE)\\ &+\sum_{l=1}^{n}\Lambda^l\left[e\left(m^l + q_E^l\left(E-\sum_{k=1}^{M}\frac{\partial E}{\partial x_k^l}x_k^l\right)\right)\sum_{h=1}^{n}\sum_{j=1}^{M}\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\right]\\ &+eE\sum_{l=1}^{n}\Lambda^l\left[\sum_{j=1}^{M}\frac{s_j^l}{\alpha^l}\frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1\\h\neq l}}^{n}\sum_{j=1}^{M}\frac{s_E^l}{\alpha^l}\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\right],\end{aligned} \tag{12}$$

in which $\Lambda^l = \lambda^l\alpha^l$, the planner's welfare weight for household l. In the third line, s_j^l and s_E^l measure the impact on household l's marginal utility of commodity j and the marginal utility of E respectively, if the household is given 1 percent extra of all commodities and suffers 1 percent extra E, see expressions (B3) and (B6) in appendix B. Dividing the terms by α^l, household l's marginal utility of income, yields a value in euro: $\frac{s_j^l}{\alpha^l}$ measures the change in household l's willingness to pay for commodity j (in euro) if the household is given 1 percent extra of all commodities and suffers one percent extra E. If $\frac{s_j^l}{\alpha^l}$ is positive (negative), it means that household l's willingness to pay for commodity j increases (decreases) when it becomes better-off. It plays an important role because it measures to what extent the valuations of all commodities have to be altered if the planner evaluates the households to be worse off than they consider themselves to be. In table 1, numerical values σ_j are provided, expressed as elasticities[3].

[3]See appendix C: $\sigma_j^l = \frac{s_j^l}{\alpha^l q_j}$.

The interpretation of expression (12) goes as follows. First, start from a situation without demerit arguments, $e = 0$. Then only the part in square brackets on the first line remains, measuring the total impact on household l's utility of the increase in t_i. It is a combination of two terms. The first one is the private impact of the increase in t_i. It is the term that appears in Ahmad & Stern (1984) as well and measures the impact of the increase in t_i on household l's utility, which is negative. The impact on the household's utility is valued using the market prices q. The second term in the first line has to do with the externality. If t_i increases, the behaviour of all other households h changes, which in turn influences E. Each extra unit of E is valued using household l's private valuation $q_E^l < 0$. Imagine that a tax increase has a negative impact on the externality. In that case $\frac{\partial W(t)}{\partial t_i}$ is smaller in absolute value, such that the societal cost of an increase in t_i decreases, as expected.

If there are demerit arguments ($e < 0$), three types of corrections can be seen in the expression. We will deal with them subsequently. First of all, the first line is multiplied with $(1 + eE) < 1$. Every unit of private utility counts for $(1 + eE)$ units of social utility. The part eE has the dimension of a budget share, measuring the total demerit value of the externality, expressed as a percentage of income. For this reason $(1 + eE)$ is the share of the households' private commodity valuation the planner takes into account. If the demerit arguments are greater, the households' private utility counts relatively less. Note that, because all the MCF are multiplied with the same number, this term does not cause any changes in their rank in itself, but decreases the absolute differences between the MCF of different commodities.

The parameter e appears in the second line of the expression as well. As in the first line, the part $\sum_{h=1}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i}$ measures the impact on E due to the change in t_i. Each extra realised tonne of CO_2 is valued by $e\left(m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l\right)\right)$, measuring how much extra the planner values a unit of E for household l (on top of q_E^l).[4] As such, it strengthens the effect of the second term in the first line. Imagine again that an increase in t_i decreases the amount of E. In that case the second line is positive, so $\frac{\partial W(t)}{\partial t_i}$ is smaller in absolute value and the MCF_i is lower. This is what is termed the 'direct' effect in the

[4]This term is expressed in euro. Remember that the demerit value of the externality e is expressed as a percentage of income. If it is multiplied with income, we get a value in euro. The term $m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l\right)$ can be seen as household l's income incorporating the value of the externality, as $q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l\right) < 0$ measures the value for household l of other households' emissions (see Cornes & Sandler (1996) who view externalities created by others as an amount of income for the individual).

introduction of this paper.

The last line of the expression is the 'scale' effect, the correction for the fact that the planner evaluates the households as worse off than they consider themselves to be. Households are evaluated at a distance eE from the utility level they consider themselves to be at and because of this commodity valuations need to be adjusted. The terms $\frac{s_j^l}{\alpha^l}$ and $\frac{s_E^l}{\alpha^l}$ measure how much the valuations of commodities and E change due to a one percent distance from the welfare level they consider themselves to be at. The first term in square brackets in the last line takes into account the change in the valuation of private commodities. In the empirical section this part will prove to have considerable influence on the rank of MCF.

The second term in the third line takes into account the impact on the valuation of the externality. It depends on $\frac{s_E^l}{\alpha^l}$, measuring the change in the households' valuation of E when they are put on a different utility level. The sign of s_E^l depends on the way households at different utility levels value the externality. If better-off households value the externality higher, the sign is negative (note that $q_E^l < 0$).

2.3 Empirical application

2.3.1 The data

In the empirical application marginal cost of funds are calculated for indirect taxes on 13 commodities in Belgium, using expression (C3) from appendix C, a simplified version of expression (12). Seven categories of information are needed: data on budget shares for 10 income deciles, the valuation of the externality, the total amount of carbon dioxide emission E, welfare weights, information on the impact of commodity consumption on E, price and cross price elasticities, and scale elasticities.

The 2004 household budget survey provides information on budgets spent on each of these 13 commodities. Table 1 contains information on the indirect tax rates on each of the commodities, the impact on CO_2 emissions of a 1000 euro increase of the expenditures on each of the commodities and their budget shares.

There are 10 household income categories and there are on average 2.33 individuals per household, which means that every income decile in Belgium consists of roughly 450 000 households. The value for q_E^h is based on the value of one ton of carbon dioxide at the world level, assumed at 20 euro per

Table 1: Data

cat.	commodity	short	tax% $\frac{t_i}{q_i}$	CO_2/1000€r_j	Budget shares w_j
1	Alcohol & Tobacco	AT	0.431	0.433	0.031
2	Food & Beverage	FB	0.058	0.392	0.088
3	Meat & Fish	MF	0.060	0.923	0.039
4	Clothing & Shoes	CL	0.172	0.100	0.047
5	Rent & Water	RW	0.046	0.362	0.215
6	Electricity	EL	0.186	1.768	0.021
7	Gas	GA	0.181	1.376	0.014
8	Other fuels (heating)	FU	0.209	1.181	0.009
9	Durables	DU	0.174	0.315	0.050
10	Services	SE	0.152	0.127	0.353
11	Car Purchase	CP	0.169	0.194	0.055
12	Car Use	CU	0.500	4.965	0.072
13	Public Transport	PT	0.057	0.202	0.007

ton. We want to know the valuation at the level of a Belgian income decile. This is calculated based on the assumption that the income elasticity of this valuation equals 1. This amounts to an average value of around 0.5 eurocents per Belgian income decile. The value for E is the total amount of CO_2 emission at the world level. The welfare weights are determined using the formula used by Ahmad & Stern: $\Lambda^l = \left(\frac{m^1}{m^h}\right)^v$, with $v \geq 0$ a measure of inequality aversion and m^1 the income of the poorest decile. In the simulations the value for v is taken to be equal to one.[5] Information on the impact of commodity consumption on the externality (for r_j^h in expression C3) is calculated from input-output analysis based on data from Belgostat (National Bank of Belgium) and from data on the amount of carbon dioxide emission per production sector.

Finally, price elasticities are derived from the estimation of a linearised almost ideal demand system (see Deaton and Muellbauer (1980)). National accounts data and price data for 54 years (1953 - 2009) are used to estimate the system of 12 budget share equations (as a SUR model, see Greene (2008)). A restricted feasible GLS is estimated and iterated with the variance-covariance matrix of the previous step used as weights in the next step. When estimating the demand system, the compensated own price elasticities of four commodity categories (alcohol & tobacco, meat & fish, other fuels and durables) appeared to be positive. This is inconsistent with demand theory, so four extra constraints have been added to the demand system, setting these compensated demand elasticities equal to 0. The scale elasticities are calculated from the compensated price elasticity matrix based on a procedure put forward by Schroyen (2010). The estimation procedure is described in appendix E and the results can be found in appendix F.

[5]This implies weights between 1 (for the poorest household) and 0.25 (for the richest household). Sensitivity analysis with values of v between 0 and 2 implies no considerable impact on the results.

Sensitivity analysis is performed for different values of e. As a reference, the IPCC calculations are based on damage estimates for a tonne of CO_2 between 6 euro and 400 euro (see e.g. Tol (2005) and Tol (2011)), so this will be the range for the simulations in this paper. In our base case, the value of one tonne of carbon dioxide emissions is equal to 20 euro (or 0.5 eurocents per income decile). The parameter e is varied so as to reflect the differences in valuation of E, simulations are performed with values of e as a multiple of the average value of a tonne of carbon dioxide. It has the dimension of a price relative to income. The parameter e ranges from zero to 20 times the average valuation of one unit of E as a percentage of income,

$$\pi_E = \frac{\sum_{l=1}^{n} q_E^l}{\sum_{l=1}^{n} m^l}.$$

This implies that the value of a tonne of carbon dioxide in the simulations lies between 20 euro and 420 euro. For these values, eE lies between 0 and -0.205, so $1 + eE$ is between 1 and 0.795, or, for the most extreme value of e, the planner considers the households to be 20.5% worse off.

Three simplifying assumptions are made for the calculation of the MCF: first, price and cross price elasticities are the same for all households: $\varepsilon_{ji}^h = \varepsilon_{ji}$ for all h. Second, it is assumed that the impact on E of commodity consumption is the same for all households: $r_j^h = r_j$ for all h, and third, it is assumed that the scale elasticities are the same for all households and that σ_E, the scale elasticity of E, equals -1. The numerator of the MCF is expression (C3) in the appendix.

2.3.2 Results

The results are shown in table 2 below in which the contribution of each component of the MCF is shown. The situation without demerit arguments is shown on the left side of the table. Numerically, only the part due to Ahmad and Stern (1984) plays a role because all terms incorporating the externality (the second term in the first line of expression (12)) are close to 0. This means that the externality does not matter much for a planner who accepts consumer sovereignty. As we move to the right in the table, demerit arguments start to play a role. These entail a number of rank switches that we will focus on.

The incorporation of demerit considerations has a multiplicative effect on each of the marginal costs of funds (see expression (12)). For each value of $e < 0$ there are four columns: each first and second column provide the rank of commodities and their marginal costs of funds taking into account the three corrections (columns 'rank' and 'MCF' respectively). Each third and fourth column (labelled 'direct' and 'scale' respectively) provides numerical information on the impact of the demerit arguments of the second and the third line of expression (12). Remember that the correction of the first line of expression (12) only decreases the relative importance of private utility, no rank switches are caused by this correction. The only consequence is that it diminishes the difference between the MCF of different commodities[6]. In the other two columns it can be seen clearly that the direct impact of the demerit arguments is numerically small, all rank switches are caused by the scale part. All direct demerit effects have a negative impact on the MCF. It makes the societal costs of an indirect tax increase slightly smaller.

Table 2

$\mathbf{e = 0}$		$\mathbf{e = 4\pi_E}$				$\mathbf{e = 8\pi_E}$				$\mathbf{e = 12\pi_E}$				$\mathbf{e = 20\pi_E}$			
rank	MCF	rank	MCF	direct	scale	rank	MCF	direct	scale	rank	MCF	direct	scale	rank	MCF	direct	scale
EL	0.900	CU	0.803	-0.0009	0.133	CU	0.901	-0.0018	0.265	CU	1.001	-0.0027	0.398	CU	1.215	-0.0044	0.664
CU	0.699	AT	0.777	-0.0001	0.111	AT	0.860	-0.0002	0.223	AT	0.942	-0.0003	0.334	AT	1.108	-0.0004	0.557
AT	0.694	EL	0.775	-0.0003	-0.089	DU	0.704	-0.0001	0.111	DU	0.733	-0.0002	0.167	CL	0.870	-0.0001	0.459
GA	0.678	DU	0.675	-0.0001	0.056	CL	0.658	-0.0000	0.184	CL	0.723	-0.0000	0.276	DU	0.791	-0.0003	0.278
MF	0.664	MF	0.614	-0.0001	-0.023	EL	0.649	-0.0006	-0.178	EL	0.523	-0.0009	-0.267	SE	0.517	-0.0001	0.142
DU	0.646	GA	0.609	-0.0001	-0.040	MF	0.564	-0.0003	-0.046	MF	0.514	-0.0004	-0.068	FB	0.440	-0.0002	0.064
CP	0.641	CP	0.590	-0.0000	-0.025	GA	0.541	-0.0002	-0.080	SE	0.499	-0.0000	0.085	MF	0.414	-0.0007	-0.114
RW	0.541	CL	0.587	-0.0000	0.092	CP	0.539	-0.0000	-0.049	CP	0.488	-0.0001	-0.074	PT	0.389	-0.0001	0.087
CL	0.517	RW	0.508	-0.0000	-0.010	SE	0.490	-0.0000	0.057	GA	0.473	-0.0003	-0.120	CP	0.386	-0.0001	-0.124
FU	0.476	SE	0.481	-0.0000	0.029	RW	0.476	-0.0001	-0.021	FB	0.453	-0.0001	0.039	RW	0.378	-0.0002	-0.052
FB	0.472	FB	0.465	-0.0000	0.013	FB	0.459	-0.0001	0.026	RW	0.443	-0.0001	-0.031	GA	0.337	-0.0006	-0.201
SE	0.472	PT	0.382	-0.0000	0.017	PT	0.384	-0.0000	0.035	PT	0.386	-0.0001	0.052	EL	0.271	-0.0015	-0.444
PT	0.381	FU	0.372	-0.0002	-0.084	FU	0.268	-0.0003	-0.168	FU	0.165	-0.0005	0.252	FU	-0.043	-0.0008	-0.421

Households are evaluated by the planner at a lower utility level, which changes their willingness to pay for each commodity. If the scale elasticity is positive (negative), the household's willingness to pay decreases (increases) on this lower utility level. In table 1 numerical values can be found for the scale elasticity for each commodity. The scale elasticities of six commodities are positive (electricity, gas, meat & fish, car purchase, other fuels and rent & water). The rank of the MCF of these commodities decrease as the value of e goes up. The reason is that the households' valuation of these commodities is considered to be lower, because of this the marginal cost of funds decreases. It is less costly for society to increase the tax on them when demerit arguments play a role, because households' valuation of these commodities are lower.

For the seven other commodities (car use, alcohol & tobacco, durables, clothing & shoes, food & beverages, services and public transport), the scale elasticities are negative. The households' valuation of these commodities is considered to be higher, because of this the marginal cost of funds increases.

[6]Going from left to right in table 2, the value for $(1 + eE)$ is 100%, 95.9%, 91.8%, 87.7% and 79.5%.

As a consequence it becomes more costly for society to increase the tax on these commodities when demerit arguments play a role. In the four right-most columns (where $e = 20\pi_E^h$), it can be seen that the commodities with a negative value in the column 'scale' rank lowest, the commodities with a positive value in this column rank highest. This implies that the incorporation of CO_2 as demerit externality stimulates the planner to put a higher tax on commodities for which the normalised willingness to pay increases when households get richer, and a lower tax on commodities for which the willingness to pay decreases when individuals get richer.

2.4 Conclusions

If households postpone decisions to decrease their emissions of carbon dioxide, they undervalue the future consequences of their behaviour and their valuation of a ton of carbond dioxide is too low. From an economic point of view, this is understood as a situation in which carbon dioxide emissions have demerit properties: the value the planner attributes to one ton of CO_2 differs from the value the households attribute to it.

In the theoretical section of the paper it is shown how the existence of these externalities with demerit properties influence the marginal cost of funds of indirect taxes and as a consequence the planner's indirect tax decisions. The marginal costs of funds of indirect taxation need to be adapted, first for the externality problem and second for demerit considerations. The consequences of incorporating the demerit arguments in the MCF are threefold. There is a direct effect due to the fact that the externality is valued higher. The second effect is a scale effect. Households are considered to be worse off than they think they are and because of this are assumed to have a different valuation for the commodities. This is taken into account in the MCF expressions using the scale elasticities of each commodity. The third correction has to do with the fact that household utility counts less relatively because the planner takes into account the consequences of something that was not valued sufficiently before. Especially the scale effects prove to be important empirically. The direct effect is numerically negligible. The third correction does not create rank switches because all MCF are multiplied with the same number.

In the empirical section MCF of indirect taxes on 13 commodities are calculated for Belgium. If only the externality is taken into account, no rank switches are realised. Only when demerit considerations are taken into account the MCF ranks switch. These rank switches are mostly due to the fact that the planner evaluates the households at a different (lower) utility level. The results suggest that the planner should put a higher (lower) tax on commodities for which the households' willingness to pay increases (decreases) when income rises. More specifically, as the planner evaluates the households further away from the utility level they consider themselves to be at, the MCF ranks of electricity, meat & fish, gas and fuels for heating decrease, and the MCF ranks of clothing & shoes, durables, food & beverage increase. A revenue-neutral welfare increasing tax reform could consist of an increase of the tax rate on the former, and an decrease of the tax rate of the latter.

This model is applied to carbon dioxide emissions as demerit externality, emitted because of the consumption of 13 different commodities. The amount and type of commodity categories is based on the division made in the household budget survey. With more specific data on categories of commodity consumption, it would be possible to calculate marginal costs of funds more specifically. Imagine, for instance, that the government distinguishes between types of car use and is able to put a lower tax rate on carpooling than on car use by one individual. Then the marginal cost of funds could be calculated for 'car use alone' and 'car use for carpooling'. This is not possible with the information at hand, since there is no information on price elasticities and on emissions. This might be a topic for future research.

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APPENDIX A: derivation of the planner's marginal willingness to pay for private goods and the externality.

Derivation of WTP expressions

We start from the following identity (see expression (2)):

$$\widetilde{u}\left(x^{l};E\right)=u^{l}\left(\underbrace{\frac{x_{1}^{l}}{1-eE}}_{\widehat{x}_{1}^{l}},\ldots,\underbrace{\frac{x_{i}^{l}}{1-eE}}_{\widehat{x}_{i}^{l}},\ldots;\underbrace{\frac{E}{1-eE}}_{\widehat{E}}\right) \tag{A1}$$
$$=u^{l}\left(\widehat{x}^{l}\left(e\right),\widehat{E}\left(e\right)\right).$$

We investigate the impact on social welfare of a change in the tax rate on commodity i. The welfare function the planner maximizes is

$$\begin{aligned} W\left(t\right) &= \sum_{l=1}^{n}\lambda^{l}\widetilde{u}\left(x^{l}\left(t\right);E\right) \\ &= \sum_{l=1}^{n}\lambda^{l}u^{l}\left(\widehat{x}^{l}\left(t\right);\widehat{E}\right). \end{aligned}$$

A change in the indirect tax rate on commodity i implies:

$$\begin{aligned} \frac{\partial W\left(t\right)}{\partial t_{i}} &= \sum_{l=1}^{n}\lambda^{l}\frac{\partial u^{l}\left(\widehat{x}^{l}\left(t\right);\widehat{E}\left(t\right)\right)}{\partial t_{i}} \\ &= \sum_{l=1}^{n}\lambda^{l}\sum_{h=1}^{n}\sum_{j=1}^{M}\frac{\partial u^{l}\left(\widehat{x}^{l};\widehat{E}\right)}{\partial x_{j}^{h}}\frac{\partial x_{j}^{h}\left(t\right)}{\partial t_{i}} \\ &= \sum_{l=1}^{n}\lambda^{l}\left[\sum_{h=1}^{n}\sum_{j=1}^{M}\left(\sum_{k=1}^{M}\frac{\partial u^{l}\left(\widehat{x}^{l};\widehat{E}\right)}{\partial\widehat{x}_{k}^{l}}\frac{\partial\widehat{x}_{k}^{l}}{\partial x_{j}^{h}}+\frac{\partial u^{l}\left(\widehat{x}^{l};\widehat{E}\right)}{\partial\widehat{E}}\frac{\partial\widehat{E}}{\partial x_{j}^{h}}\right)\frac{\partial x_{j}^{h}}{\partial q_{i}}\right]. \end{aligned} \tag{A2}$$

In the second line it can be seen that the tax increase influences all households' (indexed h) commodity consumption, which influences in turn (via E) household l's utility. In the last line we use the assumption that $\frac{\partial x_{j}^{h}}{\partial t_{i}}=\frac{\partial x_{j}^{h}}{\partial q_{i}}$. We take a closer look at the part in square brackets in the last line, measuring the impact on household l of an increase of t_i, taking into account the behavioural response of all households. It is the building block for the numerator of the MCF expressions. Call this $\omega_i^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)$:

$$\omega_i^l\left(\widehat{x}^l(e), \widehat{E}(e)\right) = \sum_{h=1}^{n}\sum_{j=1}^{M}\left(\sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l;\widehat{E}\right)}{\partial \widehat{x}_k^l}\frac{\partial \widehat{x}_k^l}{\partial x_j^h} + \frac{\partial u^l\left(\widehat{x}^l;\widehat{E}\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x_j^h}\right)\frac{\partial x_j^h}{\partial q_i}.$$

This expression can be split up in two parts: one part that has to do with household l's behavioural response and one part that has to do with the other households' behavioural response:

$$\begin{aligned}
&\omega_i^l\left(\widehat{x}^l(e), \widehat{E}(e)\right) = \\
&\sum_{j=1}^{M}\left(\sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{x}_k^l}\frac{\partial \widehat{x}_k^l}{\partial x_j^l} + \frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x_j^l}\right)\frac{\partial x_j^l}{\partial q_i} \\
&+\sum_{\substack{h=1\\h\neq l}}^{n}\left(\sum_{j=1}^{M}\left(\sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{x}_k^l}\frac{\partial \widehat{x}_k^l}{\partial x_j^h} + \frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x_j^h}\right)\frac{\partial x_j^h}{\partial q_i}\right) \\
&= \sum_{j=1}^{M}A_j^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)\frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1\\h\neq l}}^{n}\sum_{j=1}^{M}A_{jh}^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)\frac{\partial x_j^h}{\partial q_i} \qquad \text{(A3)}
\end{aligned}$$

with

$$A_j^l\left(\widehat{x}^l(e), \widehat{E}(e)\right) = \sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{x}_k^l}\frac{\partial \widehat{x}_k^l}{\partial x_j^l} + \frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x_j^l} \qquad \text{(A4)}$$

and

$$A_{jh}^l\left(\widehat{x}^l(e), \widehat{E}(e)\right) = \sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{x}_k^l}\frac{\partial \widehat{x}_k^l}{\partial x_j^h} + \frac{\partial u^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x_j^h}. \qquad \text{(A5)}$$

We want to know how expression (A3) behaves for different values of e, so we linearise it around $\omega_i^l\left(\widehat{x}^l(0), \widehat{E}(0)\right)$ to get:

$$\begin{aligned}
&\omega_i^l\left(\widehat{x}^l(e), \widehat{E}(e)\right) \approx \\
&\sum_{j=1}^{M}A_j^l\left(\widehat{x}^l(0), \widehat{E}(0)\right)\frac{\partial x_j^l}{\partial q_i} + e\sum_{j=1}^{M}\left.\frac{\partial A_j^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial e}\right|_{e=0}\frac{\partial x_j^l}{\partial q_i} \\
&+\sum_{\substack{h=1\\h\neq l}}^{n}\sum_{j=1}^{M}A_{jh}^l\left(\widehat{x}^l(0), \widehat{E}(0)\right)\frac{\partial x_j^h}{\partial q_i} + e\sum_{\substack{h=1\\h\neq l}}^{n}\sum_{j=1}^{M}\left.\frac{\partial A_{jh}^l\left(\widehat{x}^l(e), \widehat{E}(e)\right)}{\partial e}\right|_{e=0}\frac{\partial x_j^h}{\partial q_i}. \qquad \text{(A6)}
\end{aligned}$$

In order to derive the terms $\left.\frac{\partial A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e}\right|_{e=0}$ and $\left.\frac{\partial A_{jh}^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e}\right|_{e=0}$ we need expressions for $A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)$ and $A_{jh}^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)$.

Derivation of $A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)$ and $A_{jh}^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)$.

In expressions (A4) and (A5) it is clear that there is an effect on utility through the consumption of private commodities and through E. First of all remember that $\widehat{x}_j^h = x_j^h(1-eE)^{-1}$ and $\widehat{E} = E(1-eE)^{-1}$. Based on this, we calculate $\frac{\partial \widehat{x}_j^h}{\partial x_i^l}$ for all k,l and $\frac{\partial \widehat{E}}{\partial x_i^l}$. Observe that the expression for $\frac{\partial \widehat{x}_i^h}{\partial x_i^h}$ will look a bit different because x_i^h influences $\widehat{x}_i^h$ both directly and indirectly via the effect on E:

$$\frac{\partial \widehat{x}_i^l}{\partial x_i^l} = \frac{1}{1-eE} + \frac{e x_j^l}{(1-eE)^2}\frac{\partial E}{\partial x_i^l},$$

$$\frac{\partial \widehat{x}_k^l}{\partial x_j^h} = \frac{e x_k^l}{(1-eE)^2}\frac{\partial E}{\partial x_j^h},$$

and

$$\begin{aligned}\frac{\partial \widehat{E}}{\partial x_j^h} &= \left[\frac{1}{1-eE} + \frac{eE}{(1-eE)^2}\right]\frac{\partial E}{\partial x_j^h} \\ &= \frac{1}{(1-eE)^2}\frac{\partial E}{\partial x_j^h}.\end{aligned}$$

Now we fill in these in expression (A4) and (A5) to get

$$\begin{aligned}A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right) &= \sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial \widehat{x}_k^l}\frac{\partial \widehat{x}_k^l}{\partial x_j^l} + \frac{\partial u^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x_j^l} \\ &= \frac{1}{1-eE}\frac{\partial u^l}{\partial \widehat{x}_j^l} + \sum_{k=1}^{M}\frac{\partial u^l}{\partial \widehat{x}_k^l}\frac{e x_k^l}{(1-eE)^2}\frac{\partial E}{\partial x_j^l} + \frac{\partial u^l}{\partial \widehat{E}}\frac{1}{(1-eE)^2}\frac{\partial E}{\partial x_j^l} \qquad \text{(A7)}\end{aligned}$$

and

$$
\begin{aligned}
A^l_{jh}\left(\widehat{x}^l(e),\widehat{E}(e)\right) &= \sum_{k=1}^{M}\frac{\partial u^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial \widehat{x}^l_k}\frac{\partial \widehat{x}^l_k}{\partial x^h_j}+\frac{\partial u^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial \widehat{E}}\frac{\partial \widehat{E}}{\partial x^h_j}\\
&= \sum_{k=1}^{M}\frac{\partial u^l}{\partial \widehat{x}^l_k}\frac{ex^l_k}{(1-eE)^2}\frac{\partial E}{\partial x^h_j}+\frac{\partial u^l}{\partial \widehat{E}}\frac{1}{(1-eE)^2}\frac{\partial E}{\partial x^h_j}. \qquad \text{(A8)}
\end{aligned}
$$

Observe that, from expression (A7),

$$
A^l_j\left(\widehat{x}^l(0),\widehat{E}(0)\right)=\frac{\partial u^l}{\partial x^l_j}+\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x^l_j}, \qquad \text{(A9)}
$$

and from (A8)

$$
A^l_{jh}\left(\widehat{x}^l(0),\widehat{E}(0)\right)=\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x^h_j} \qquad \text{(A10)}
$$

The linearization

In order to facilitate the derivation, we start by multiplying expressions (A7) and (A8) with $(1-eE)^2$ to get

$$
(1-eE)^2 A^l_j\left(\widehat{x}^l(e),\widehat{E}(e)\right)=(1-eE)\frac{\partial u^l}{\partial \widehat{x}^l_j}+\sum_{k=1}^{M}\frac{\partial u^l}{\partial \widehat{x}^l_k}ex^l_k\frac{\partial E}{\partial x^l_j}+\frac{\partial u^l}{\partial \widehat{E}}\frac{\partial E}{\partial x^l_j}, \qquad \text{(A11)}
$$

and

$$
(1-eE)^2 A^l_{jh}\left(\widehat{x}^l(e),\widehat{E}(e)\right)=\sum_{k=1}^{M}\frac{\partial u^l}{\partial \widehat{x}^l_k}ex^l_k\frac{\partial E}{\partial x^h_j}+\frac{\partial u^l}{\partial \widehat{E}}\frac{\partial E}{\partial x^h_j} \qquad \text{(A12)}
$$

Observe that, for the linearisation, the derivative of the left hand side of expression (A11) with respect to e is

$$
\begin{aligned}
\frac{\partial\left[(1-eE)^2 A^l_j\left(\widehat{x}^l(e),\widehat{E}(e)\right)\right]}{\partial e} &= 2(1-eE)(-E)A^l_j\left(\widehat{x}^l(e),\widehat{E}(e)\right)\\
&\quad +(1-eE)^2\frac{\partial A^l_j\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e},
\end{aligned}
$$

evaluated at $e=0$, we get

$$\left.\frac{\partial\left[(1-eE)^2 A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)\right]}{\partial e}\right|_{e=0} = \\ -2EA_j^l\left(\widehat{x}^l(0),\widehat{E}(0)\right)+\left.\frac{\partial A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e}\right|_{e=0},$$

so

$$\left.\frac{\partial A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e}\right|_{e=0} = \\ \left.\frac{\partial\left[(1-eE)^2 A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)\right]}{\partial e}\right|_{e=0}+2EA_j^l\left(\widehat{x}^l(0),\widehat{E}(0)\right). \tag{A13}$$

A similar expression can be derived for $\left.\frac{\partial A_{jh}^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e}\right|_{e=0}$.

Now we are ready to calculate the derivatives. The derivative of expression (A11) evaluated at $e=0$ is (remember that the marginal utilities depend on the parameter e)

$$\left.\frac{\partial\left[(1-eE)^2 A_j^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)\right]}{\partial e}\right|_{e=0} = -E\frac{\partial u^l}{\partial x_j^l}+\sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l\frac{\partial E}{\partial x_j^l} \\ +\sum_{k=1}^{M}\frac{\partial^2 u^l}{\partial x_j^l\partial x_k^l}x_k^l E+\frac{\partial^2 u^l}{\partial x_j^l\partial E}EE \\ +\sum_{k=1}^{M}\frac{\partial^2 u^l}{\partial E\partial x_k^l}x_k^l E\frac{\partial E}{\partial x_j^l}+\frac{\partial^2 u^l}{(\partial E)^2}EE\frac{\partial E}{\partial x_j^l}. \tag{A14}$$

The derivative of expression (A12) evaluated at $e=0$ is

$$\left.\frac{\partial\left[(1-eE)^2 A_{jh}^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)\right]}{\partial e}\right|_{e=0} = \\ \sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l\frac{\partial E}{\partial x_j^h}+\sum_{k=1}^{M}\frac{\partial^2 u^l}{\partial E\partial x_k^l}x_k^l E\frac{\partial E}{\partial x_j^h}+\frac{\partial^2 u^l}{(\partial E)^2}EE\frac{\partial E}{\partial x_j^h} \tag{A15}$$

This implies for expression (A13), taking into account expression (A9) and (A14):

$$\left.\frac{\partial A_j^l\left(\widehat{x}^l\left(e\right),\widehat{E}\left(e\right)\right)}{\partial e}\right|_{e=0} = -E\frac{\partial u^l}{\partial x_j^l} + \sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l\frac{\partial E}{\partial x_j^l}$$
$$+\sum_{k=1}^{M}\frac{\partial^2 u^l}{\partial x_j^l \partial x_k^l}x_k^l E + \frac{\partial^2 u^l}{\partial x_j^l \partial E}EE$$
$$+\sum_{k=1}^{M}\frac{\partial^2 u^l}{\partial E \partial x_k^l}x_k^l E\frac{\partial E}{\partial x_j^l} + \frac{\partial^2 u^l}{\left(\partial E\right)^2}EE\frac{\partial E}{\partial x_j^l}$$
$$+2E\left(\frac{\partial u^l}{\partial x_j^l} + \frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right).$$

Now take into account expression (B3) from appendix B,

$$\left.\frac{\partial A_j^l\left(\widehat{x}^l\left(e\right),\widehat{E}\left(e\right)\right)}{\partial e}\right|_{e=0} = -E\frac{\partial u^l}{\partial x_j^l} + \sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l\frac{\partial E}{\partial x_j^l} + s_j^l E$$
$$+2E\left(\frac{\partial u^l}{\partial x_j^l} + \frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right).$$

Rearrange slightly to have

$$\left.\frac{\partial A_j^l\left(\widehat{x}^l\left(e\right),\widehat{E}\left(e\right)\right)}{\partial e}\right|_{e=0} =$$
$$\left(\frac{\partial u^l}{\partial x_j^l} + \frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right)E + \left(\sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l + \frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^l} + s_j^l E. \tag{A16}$$

For $\left.\frac{\partial A_{jh}^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)}{\partial e}\right|_{e=0}$ we take into account expressions (A13), (A10) and (A15) to have

$$\left.\frac{\partial A_{jh}^l\left(\widehat{x}^l\left(e\right),\widehat{E}\left(e\right)\right)}{\partial e}\right|_{e=0}$$
$$\sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l\frac{\partial E}{\partial x_j^h} + \sum_{k=1}^{M}\frac{\partial^2 u^l}{\partial E \partial x_k^l}x_k^l E\frac{\partial E}{\partial x_j^h} + \frac{\partial^2 u^l}{\left(\partial E\right)^2}EE\frac{\partial E}{\partial x_j^h} + 2E\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}.$$

Take into account expression (B6) and rearranging slightly to get

$$\left.\frac{\partial A_{jh}^l\left(\widehat{x}^l\left(e\right),\widehat{E}\left(e\right)\right)}{\partial e}\right|_{e=0} =$$
$$\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}E + \left(\sum_{k=1}^{M}\frac{\partial u^l}{\partial x_k^l}x_k^l + \frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^h} + s_E^l E\frac{\partial E}{\partial x_j^h}. \tag{A17}$$

Now we can fill in expressions (A9), (A10), (A16) and (A17) in expression (A6) to have

$$
\begin{aligned}
&\omega_i^l\left(\widehat{x}^l(e),\widehat{E}(e)\right)\approx\sum_{j=1}^M\left(\frac{\partial u^l}{\partial x_j^l}+\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right)\frac{\partial x_j^l}{\partial q_i}\\
&+e\sum_{j=1}^M\left(\left(\frac{\partial u^l}{\partial x_j^l}+\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right)E+\left(\sum_{k=1}^M\frac{\partial u^l}{\partial x_k^l}x_k^l+\frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^l}+s_j^lE\right)\frac{\partial x_j^l}{\partial q_i}\\
&+\sum_{\substack{h=1\\h\neq l}}^n\sum_{j=1}^M\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\\
&+e\sum_{\substack{h=1\\h\neq l}}^n\sum_{j=1}^M\left(\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}E+\left(\sum_{k=1}^M\frac{\partial u^l}{\partial x_k^l}x_k^l+\frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^h}+s_E^lE\frac{\partial E}{\partial x_j^h}\right)\frac{\partial x_j^h}{\partial q_i}.
\end{aligned}
$$

This is the building block for the marginal cost of funds expressions, fill it in in expression (A2):

$$
\begin{aligned}
\frac{\partial W(t)}{\partial t_i}&=\sum_{l=1}^n\lambda^l\left[\sum_{j=1}^M\left(\frac{\partial u^l}{\partial x_j^l}+\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right)\frac{\partial x_j^l}{\partial q_i}\right]\\
&+\sum_{l=1}^n\lambda^l\left[e\sum_{j=1}^M\left(\left(\frac{\partial u^l}{\partial x_j^l}+\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right)E+\left(\sum_{k=1}^M\frac{\partial u^l}{\partial x_k^l}x_k^l+\frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^l}+s_j^lE\right)\frac{\partial x_j^l}{\partial q_i}\right]\\
&+\sum_{l=1}^n\lambda^l\left[\sum_{\substack{h=1\\h\neq l}}^n\sum_{j=1}^M\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\right]\\
&+\sum_{l=1}^n\lambda^l\left[e\sum_{\substack{h=1\\h\neq l}}^n\sum_{j=1}^M\left(\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}E+\left(\sum_{k=1}^M\frac{\partial u^l}{\partial x_k^l}x_k^l+\frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^h}+s_E^lE\frac{\partial E}{\partial x_j^h}\right)\frac{\partial x_j^h}{\partial q_i}\right]
\end{aligned}
\tag{A18}
$$

Rearrange to get

$$
\begin{aligned}
\frac{\partial W(t)}{\partial t_i}&=\sum_{l=1}^n\lambda^l\left[\sum_{j=1}^M\left(\frac{\partial u^l}{\partial x_j^l}+\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}\right)\frac{\partial x_j^l}{\partial q_i}+\sum_{\substack{h=1\\h\neq l}}^n\sum_{j=1}^M\frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\right](1+eE)\\
&+e\sum_{l=1}^n\lambda^l\left[\sum_{h=1}^n\sum_{j=1}^M\left(\left(\sum_{k=1}^M\frac{\partial u^l}{\partial x_k^l}x_k^l+\frac{\partial u^l}{\partial E}E\right)\frac{\partial E}{\partial x_j^h}\right)\frac{\partial x_j^h}{\partial q_i}\right]\\
&+eE\sum_{l=1}^n\lambda^l\left[\sum_{j=1}^M s_j^l\frac{\partial x_j^l}{\partial q_i}+\sum_{\substack{h=1\\h\neq l}}^n\sum_{j=1}^M s_E^l\frac{\partial E}{\partial x_j^h}\frac{\partial x_j^h}{\partial q_i}\right].
\end{aligned}
$$

Now note that the term in round brackets in the square bracketed term in the first line equals $\alpha^l q_j$ with α^l

household l's marginal utility of income[7]:

$$\begin{aligned}\frac{\partial W(t)}{\partial t_i} &= \sum_{l=1}^{n} \lambda^l \left[\sum_{j=1}^{M} \alpha^l q_j \frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1 \\ h\neq l}}^{n} \sum_{j=1}^{M} \frac{\partial u^l}{\partial E} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] (1+eE) \\ &+ e \sum_{l=1}^{n} \lambda^l \left[\left(\sum_{k=1}^{M} \frac{\partial u^l}{\partial x_k^l} x_k^l + \frac{\partial u^l}{\partial E} E \right) \sum_{h=1}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] \\ &+ eE \sum_{l=1}^{n} \lambda^l \left[\sum_{j=1}^{M} s_j^l \frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1 \\ h\neq l}}^{n} \sum_{j=1}^{M} s_E^l \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right]. \end{aligned} \tag{A19}$$

Divide and multiply the second term in the first line, the second and the third line with α^l to get

$$\begin{aligned}\frac{\partial W(t)}{\partial t_i} &= \sum_{l=1}^{n} \lambda^l \alpha^l \left[\sum_{j=1}^{M} q_j \frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1 \\ h\neq l}}^{n} \sum_{j=1}^{M} \frac{\frac{\partial u^l}{\partial E}}{\alpha^l} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] (1+eE) \\ &+ e \sum_{l=1}^{n} \lambda^l \alpha^l \left[\left(\sum_{k=1}^{M} \frac{\frac{\partial u^l}{\partial x_k^l}}{\alpha^l} x_k^l + \frac{\frac{\partial u^l}{\partial E}}{\alpha^l} E \right) \sum_{h=1}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] \\ &+ eE \sum_{l=1}^{n} \lambda^l \alpha^l \left[\sum_{j=1}^{M} \frac{s_j^l}{\alpha^l} \frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1 \\ h\neq l}}^{n} \sum_{j=1}^{M} \frac{s_E^l}{\alpha^l} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right]. \end{aligned} \tag{A20}$$

Now take into account expression (3),

$$q_E^l = \frac{\frac{\partial u^l}{\partial E}}{\alpha^l},$$

household l's valuation of a unit of E, split the second part of the term in round brackets in the second line and take into account expressions (2) and (3) to have

$$\begin{aligned}\sum_{k=1}^{M} \frac{\frac{\partial u^l}{\partial x_k^l}}{\alpha^l} x_k^l + \frac{\frac{\partial u^l}{\partial E}}{\alpha^l} E &= \sum_{k=1}^{M} \frac{\frac{\partial u^l}{\partial x_k^l}}{\alpha^l} x_k^l + \frac{\frac{\partial u^l}{\partial E}}{\alpha^l} \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l + \frac{\frac{\partial u^l}{\partial E}}{\alpha^l} \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l \right) \\ &= m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l \right). \end{aligned} \tag{A21}$$

[7]Household l's consumption bundle is the solution to the maximization of Lagrangian $L = u^l\left(x^l; E\right) - \alpha^l \left(\sum_{j=1}^{M} x_j^l q_j - m^l \right)$. The first order condition for commodity j is $\frac{\partial u^l\left(x^l;E\right)}{\partial x_j^l} + \frac{\partial u^l\left(x^l;E\right)}{\partial E} \frac{\partial E}{\partial x_j^l} = \alpha^l q_j$.

Finally fill in expression (A21) in expression (A20) and set $\lambda^l \alpha^l = \Lambda^l$:

$$\frac{\partial W(t)}{\partial t_i} = \sum_{l=1}^{n} \Lambda^l \left[\sum_{j=1}^{M} q_j \frac{\partial x_j^l}{\partial q_i} + q_E^l \sum_{\substack{h=1 \\ h \neq l}}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] (1 + eE)$$
$$+ \sum_{l=1}^{n} \Lambda^l \left[e \left(m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l \right) \right) \sum_{h=1}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right]$$
$$+ eE \sum_{l=1}^{n} \Lambda^l \left[\sum_{j=1}^{M} \frac{s_j^l}{\alpha^l} \frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1 \\ h \neq l}}^{n} \sum_{j=1}^{M} \frac{s_E^l}{\alpha^l} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right]. \tag{A22}$$

APPENDIX B: Derivation of the scale effects

The scale effects provide information on how household l's marginal utility of commodity i changes when all commodity consumption levels and E change. Start from expression (A9) and assume only linear effects of commodity consumption on E, so $\frac{\partial^2 E}{\partial x_i^h \partial x_r^h} = 0$ for all r. Household l's marginal utility of commodity j is

$$A_j^l\left(\widehat{x}^l(0), \widehat{E}(0)\right) = \frac{\partial u^l}{\partial x_j^l} + \frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^l}.$$

Take the derivative of this expression with respect to x_r^l, multiply with x_r^l and sum over all r to get

$$\sum_{r=1}^{M} \frac{\partial A_j^l\left(\widehat{x}^l(0), \widehat{E}(0)\right)}{\partial x_r^l} x_r^l = \sum_{r=1}^{M} \frac{\partial^2 u^l}{\partial x_j^l \partial x_r^l} x_r^l + \sum_{r=1}^{M} \frac{\partial^2 u^l}{\partial E \partial x_r^l}\frac{\partial E}{\partial x_j^l} x_r^l. \tag{B1}$$

Take the derivative of the expression with respect to E and multiply with E to have

$$\frac{\partial A_j^l\left(\widehat{x}^l(0), \widehat{E}(0)\right)}{\partial E} E = \frac{\partial^2 u^l}{\partial x_j^l \partial E} E + \frac{\partial^2 u^l}{(\partial E)^2}\frac{\partial E}{\partial x_j^l} E. \tag{B2}$$

Take the sum of expressions (B1) and (B2) and call it s_j^l:

$$s_j^l = \sum_{r=1}^{M} \frac{\partial^2 u^l}{\partial x_j^l \partial x_r^l} x_r^l + \sum_{r=1}^{M} \frac{\partial^2 u^l}{\partial E \partial x_r^l}\frac{\partial E}{\partial x_j^l} x_r^l + \frac{\partial^2 u^l}{\partial x_j^l \partial E} E + \frac{\partial^2 u^l}{(\partial E)^2}\frac{\partial E}{\partial x_j^l} E \tag{B3}$$

measuring the impact on household l's marginal utility of commodity j if all commodities and E increase with 1 percent.

From expression (A10),

$$A_{jh}^l\left(\widehat{x}^l(0), \widehat{E}(0)\right) = \frac{\partial u^l}{\partial E}\frac{\partial E}{\partial x_j^h}$$

we derive in the same way

$$\sum_{r=1}^{M} \frac{\partial A_{jh}^l\left(\widehat{x}^l(0), \widehat{E}(0)\right)}{\partial x_r^l} x_r^l = \frac{\partial E}{\partial x_j^h} \sum_{r=1}^{M} \frac{\partial^2 u^l}{\partial E \partial x_r^l} x_r^l \tag{B4}$$

and

$$\frac{\partial A_{jh}^{l}\left(\widehat{x}^{l}\left(0\right),\widehat{E}\left(0\right)\right)}{\partial E}E=\frac{\partial E}{\partial x_{j}^{h}}\frac{\partial^{2}u^{l}}{\left(\partial E\right)^{2}}E \tag{B5}$$

Taking the sum of expressions (B4) and (B5), we have

$$s_{E}^{l}=\frac{\partial E}{\partial x_{j}^{h}}\sum_{r=1}^{M}\frac{\partial^{2}u^{l}}{\partial E\partial x_{r}^{l}}x_{r}^{l}+\frac{\partial E}{\partial x_{j}^{h}}\frac{\partial^{2}u^{l}}{\left(\partial E\right)^{2}}E \tag{B6}$$

APPENDIX C: derivation of the MCF_i formulae used in the empirical section.

Derivation of the numerator of the MCF_i formulae

First turn back to expression (A22) and take into account that $\sum_{j=1}^{M} q_j \frac{\partial x_j^l}{\partial q_i} = -x_i^l$.[8]

$$\begin{aligned}\frac{\partial W(t)}{\partial t_i} &= \sum_{l=1}^{n} \Lambda^l \left[-x_i^l + \sum_{\substack{h=1\\h\neq l}}^{n} \sum_{j=1}^{M} q_E^l \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] (1+eE) \\ &\quad + e \sum_{l=1}^{n} \Lambda^l \left[\left(m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l \right) \right) \sum_{h=1}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right] \\ &\quad + eE \sum_{l=1}^{n} \Lambda^l \left[\sum_{j=1}^{M} \frac{s_j^l}{\alpha^l} \frac{\partial x_j^l}{\partial q_i} + \sum_{\substack{h=1\\h\neq l}}^{n} \sum_{j=1}^{M} \frac{s_E^l}{\alpha^l} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} \right].\end{aligned}$$

Now multiply with q_i to get

$$\begin{aligned}\frac{\partial W(t)}{\partial t_i} q_i = & \sum_{l=1}^{n} \Lambda^l \left[-q_i x_i^l + \sum_{\substack{h=1\\h\neq l}}^{n} \sum_{j=1}^{M} q_E^l \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i \right] (1+eE) \\ & + e \sum_{l=1}^{n} \Lambda^l \left[\left(m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l \right) \right) \sum_{h=1}^{n} \sum_{j=1}^{M} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i \right] \\ & + eE \sum_{l=1}^{n} \Lambda^l \left[\sum_{j=1}^{M} \frac{s_j^l}{\alpha^l} \frac{\partial x_j^l}{\partial q_i} q_i + \sum_{\substack{h=1\\h\neq l}}^{n} \sum_{j=1}^{M} \frac{s_E^l}{\alpha^l} \frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i \right]. \qquad \text{(C1)}\end{aligned}$$

Now transform derivatives into elasticities; $\varepsilon_{ji}^l = \frac{\partial x_j^l}{\partial q_i} \frac{q_i}{x_j^l}$. For the first and the second line, take into account that $\frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i = \frac{\partial E}{\partial \left(q_j x_j^h\right)} \frac{\partial \left(q_j x_j^h\right)}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i$ and note that $\frac{\partial E}{\partial \left(q_j x_j^h\right)} \frac{\partial \left(q_j x_j^h\right)}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i = \frac{\partial E}{\partial \left(q_j x_j^h\right)} q_j \frac{\partial x_j^l}{\partial q_i} \frac{q_i}{x_j^h} x_j^h = \varepsilon_{ji}^h x_j^h q_j$. This implies that

$$\frac{\partial E}{\partial x_j^h} \frac{\partial x_j^h}{\partial q_i} q_i = r_j^h \varepsilon_{ji}^h x_j^h q_j$$

with $r_j^h = \frac{\partial E}{\partial \left(q_j x_j^h\right)}$.

For the first term in square brackets in the third line, note that $\frac{s_j^l}{\alpha^l}$ is the impact of a percentage increase in all commodities and E on household l's valuation of commodity j. If it is divided by q_j, we have a

[8]To see this, differentiate the identity $\sum_{j=1}^{M} x_j^l q_j = m^l$ with respect to q_i to have $\sum_{j=1}^{M} \frac{\partial x_j^l}{\partial q_i} q_j + x_i^l = 0$.

scale elasticity, so $\sigma_j^l = \frac{s_j^l}{\alpha^l q_j}$. It implies that

$$\begin{aligned} \frac{s_j^l}{\alpha^l} \frac{\partial x_j^l}{\partial q_i} q_i \frac{q_j x_j^l}{q_j x_j^l} &= \sigma_j^l \frac{\partial x_j^l}{\partial q_i} \frac{q_i}{x_j^l} q_j x_j^l \\ &= \sigma_j^l \varepsilon_{ji}^l q_j x_j^l . \end{aligned}$$

It measures the change in household l's valuation of commodity j due to the increase in the tax on commodity i.

Finally, multiply and divide the second term in the third line by q_E^l and note that $\sigma_E^l = \frac{s_E^l}{\alpha^l q_E^l}$ is the scale elasticity of the valuation of E by household l. It measures with what percentage the valuation of E changes if household l gets a percent more commodities and E.

Use these to fill in in expression (C1):

$$\begin{aligned} \frac{\partial W(t)}{\partial t_i} q_i = & \sum_{l=1}^{n} \Lambda^l \left[-q_i x_i^l + q_E^l \sum_{\substack{h=1 \\ h \neq l}}^{n} \sum_{j=1}^{M} r_j^h \varepsilon_{ji}^h x_j^h q_j \right] (1 + eE) \\ & + e \sum_{l=1}^{n} \Lambda^l \left[\left(m^l + q_E^l \left(E - \sum_{k=1}^{M} \frac{\partial E}{\partial x_k^l} x_k^l \right) \right) \sum_{h=1}^{n} \sum_{j=1}^{M} r_j^h \varepsilon_{ji}^h x_j^h q_j \right] \\ & + eE \sum_{l=1}^{n} \Lambda^l \left[\sum_{j=1}^{M} \sigma_j^l \varepsilon_{ji}^l q_j x_j^l + q_E^l \sum_{\substack{h=1 \\ h \neq l}}^{n} \sum_{j=1}^{M} \sigma_E^l r_j^h \varepsilon_{ji}^h x_j^h q_j \right], \end{aligned} \tag{C2}$$

a simplified version of which will be used in the numerical application:

$$\begin{aligned} \frac{\partial W(t)}{\partial t_i} q_i = & \sum_{l=1}^{n} \Lambda^l \left[-q_i x_i^l + q_E^l \sum_{\substack{h=1 \\ h \neq l}}^{n} \sum_{j=1}^{M} r_j \varepsilon_{ji} x_j^h q_j \right] (1 + eE) \\ & + e \sum_{l=1}^{n} \Lambda^l \left[\left(m^l + q_E^l E \right) \sum_{h=1}^{n} \sum_{j=1}^{M} r_j \varepsilon_{ji} x_j^h q_j \right] \\ & + eE \sum_{l=1}^{n} \Lambda^l \left[\sum_{j=1}^{M} \sigma_j \varepsilon_{ji} q_j x_j^l + q_E^l \sum_{\substack{h=1 \\ h \neq l}}^{n} \sum_{j=1}^{M} \sigma_E r_j \varepsilon_{ji} x_j^h q_j \right], \end{aligned} \tag{C3}$$

APPENDIX D: From private utility to public utility

Define $\widetilde{u}\left(x^h;E\right)$ as

$$\widetilde{u}\left(\frac{x^h}{d^{ph}\left(x^h,\overline{u^h};E\right)};\frac{E}{d^{ph}\left(x^h,\overline{u^h};E\right)}\right)=\overline{u^h}.$$

If $d^{ph}\left(x^h,\overline{u^h};E\right)=1$, then $\widetilde{u}\left(x^h;E\right)=\overline{u^h}$. Now use expressions (6) and (7) to get

$$u^h\left(\frac{x^h}{d^{ph}\left(x^h,\overline{u^h};E\right)-eE};\frac{E}{d^{ph}\left(x^h,\overline{u^h};E\right)-eE}\right)=\overline{u^h},$$

which implies that

$$\widetilde{u}\left(\frac{x^h}{d^{ph}\left(x^h,\overline{u^h};E\right)};\frac{E}{d^{ph}\left(x^h,\overline{u^h};E\right)}\right)=u^h\left(\frac{x^h}{d^{ph}\left(x^h,\overline{u^h};E\right)-eE};\frac{E}{d^{ph}\left(x^h,\overline{u^h};E\right)-eE}\right).$$

If this expression is evaluated at $d^{ph}\left(x^h,\overline{u^h};E\right)=1$ (this means that the planner evaluates the household at the bundle he is actually consuming) we get the required expression.

APPENDIX E: Estimation

In order to calculate the price, cross price and scale elasticities needed for the calculation of the marginal cost of funds expressions, a demand system needs to be estimated. We estimate the linearized almost ideal demand system (LA-AIDS) of Deaton and Muellbauer (1980) as a seemingly unrelated regression model (SUR). We use data on the consumption of 13 commodities, for the period of 1953-2009, for Belgium. The budget share data and price data are based on the national accounts. The observations of 1992-1994 are not included, as the data collection method differed in these years. There are 54 years of observations and all years before 1992 get a dummy.

The 13 budget shares are

$$w_i = \alpha_i + \sum_{j=1}^{13} \gamma_{ij} \log q_j + \beta_i \log \left(\frac{m}{P}\right) + \delta_i d \tag{E1}$$

with q_j the price of commodity j, with m the amount of income, P a price index and d a year dummy. For simplicity, the price index P is approximated by Stone's index $\log P^* = \sum_i^{13} w_i \log q_i$. With $P \cong \Psi P^*$, we can write

$$w_i = (\alpha_i - \beta_i \log \Psi) + \sum_{j=1}^{13} \gamma_{ij} \log q_j + \beta_i \log \left(\frac{m}{P^*}\right) + \delta_i d \tag{E2}$$

In total there are 13 equations with 16 parameters, so 208 parameters to estimate. Demand theory prescribes a number of restrictions on the parameters of this model:

$$\sum_{i=1}^{13} \alpha_i = 1 \quad \sum_{i=1}^{13} \gamma_{ij} = 0 \quad \sum_{j=1}^{13} \gamma_{ij} = 0 \quad \sum_{i=1}^{13} \beta_i = 1 \quad \sum_{i=1}^{13} \delta_i = 0$$
$$\gamma_{ij} = \gamma_{ji} \tag{E3}$$

As the sum of all budget shares in expression (E2) equals one by definition, this is a singular system. In order to be able to estimate the system, one equation is omitted, the coefficients of this equation can be determined by the restrictions in expression (E3). It has been shown that it does not matter which equation is omitted (see Wooldridge (2002)). Using the fact that $\gamma_{i13} = -\sum_{j=1}^{12} \gamma_{ij}$, and with $\alpha_i^* = \alpha_i - \beta_i \log \Psi$, expression (E2) can be written in estimable form as

$$w_i = \alpha_i^* + \sum_{j=1}^{12} \gamma_{ij} \log \frac{q_j}{q_{13}} + \beta_i \log \left(\frac{m}{P^*} \right) + \delta_i d + u_i, \tag{E4}$$

with u_i disturbance. The number of parameters to estimate has decreased, now there are 12 equations with 15 parameters and in total 66 restrictions, so there are $180 - 66 = 114$ parameters to estimate. More specifically, with y a 648×1 matrix with budget shares (12 times 54 observations of budget shares), a 648×180 block diagonal data matrix X containing 12 blocks of 54×15 data matrices x containing a column of ones, 12 relative prices, real income and the year dummy. In matrix notation, we want to estimate the coefficients of

$$\begin{aligned} y &= Xb + u \\ \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_{12} \end{bmatrix} &= \begin{bmatrix} x & 0 & \cdots & 0 \\ 0 & x & 0 & 0 \\ \vdots & 0 & \ddots & 0 \\ 0 & 0 & 0 & x \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_{12} \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_{12} \end{bmatrix} \end{aligned}$$

The estimation procedure we use for the system of equations is iterative feasible generalized least squares, which provides an efficient estimator (Wooldridge (2002)) that converges to the full information maximum likelihood estimator (Kmenta and Gilbert (1968)). First a restricted OLS regression is performed to estimate the 114 parameters, then based on the residuals $\widehat{u}$ a variance covariance matrix is estimated to perform the GLS estimation in the next step. This procedure is repeated until convergence. The OLS estimator can be calculated using a 66×180 matrix R with restrictions and a 66×1 vector r of zeroes, the restricted 180×1 OLS coefficient vector b_{OLS} can be calculated as (see Johnston and Di Nardo (1997)):

$$b_{OLS} = (X'X)^{-1} X'y + (X'X)^{-1} R' \left[R (X'X)^{-1} R' \right]^{-1} \left(r - R \left((X'X)^{-1} X'y \right) \right).$$

With the error terms of this regression, a 12×12 variance covariance matrix is estimated, the kronecker product of which is Ω, a 648×648 variance coveriance matrix. This matrix is used as weights in the next step of the feasible generalized least squares calculation:

$$b^* = \left(X'\Omega^{-1}X\right)^{-1} X'\Omega^{-1}y$$
$$+ \left(X'\Omega^{-1}X\right)^{-1} R' \left[R\left(X'\Omega^{-1}X\right)^{-1} R'\right]^{-1} \left(r - R\left(\left(X'\Omega^{-1}X\right)^{-1} X'\Omega^{-1}y\right)\right). \tag{E5}$$

This procedure is repeated until the parameters converge. The estimates of b^* are such that four of the compensated own price elasticities are above zero (commodities 1, 3, 8 and 9). Four extra restrictions are imposed on the system in order to make sure that the compensated own price elasticity are equal to zero. This implies that the matrix R becomes a 70×180 matrix and r a 70×1 matrix with restrictions.

With the parameter estimates for expression (E4) in hand, uncompensated (Marhallian) price elasticity can be calculated as in Green and Alston (1990)[9]:

$$\varepsilon_{ij} = -\theta_{ij} + \frac{\gamma_{ij} - \beta_i w_j}{w_i}, \tag{E6}$$

with $\theta_{ij} = 1$ when $i = j$ and zero otherwise, and the compensated (Hicksian) elasticities can be calculated as

$$\varepsilon^c_{ij} = \varepsilon_{ij} + w_j\left(1 + \frac{\beta_i}{w_i}\right). \tag{E7}$$

Income elasticities can be calculated as

$$\varepsilon_{im} = 1 + \frac{\beta_i}{w_i}. \tag{E8}$$

The scale elasticities can be calculated based on a procedure put forward by Schroyen (2010). They measure with what percentage the willingness to pay for a commodity changes if the consumer is put on a different consumption level. The procedure goes as follows. Let w be a column vector with the 13 budget

[9]In fact, $\varepsilon_{ij} = -\theta_{ij} + \frac{1}{w_i}\left(\gamma_{ij} - \beta_i \frac{\partial \log P^*}{\partial \log q_j}\right)$, and $\frac{\partial \log P^*}{\partial \log q_j} = w_j + \sum_{k=1}^{13} w_k \log q_k \frac{\partial \log w_k}{\partial \log q_j}$. The last part of the latter expression is assumed to be zero, hence expression (E6) follows.

shares in one year. Based on this, a diagonal matrix W is created:

$$W = \begin{bmatrix} w_1 & & 0 \\ & \ddots & \\ 0 & & w_{13} \end{bmatrix},$$

let E be a 13 by 13 matrix of compensated price elasticities, and M a vector with 13 income elasticities. Now calculate $S = WE$ and $b = WM$. Now the matrix $\begin{bmatrix} S & w \\ w' & 0 \end{bmatrix}$ can be formed, the inverse of which is $\begin{bmatrix} T & 1 \\ 1 & 0 \end{bmatrix}$. The vector of scale elasticities can be calculated as $\sigma = -(Tb + 1)$, see (Schroyen (2010)).

Appendix F: Data and results

cat.	commodity	short	tax% $\frac{t_i}{q_i}$	CO_2/1000€ r_j	σ_j [10]	w_j	ε_{ii}^{Hicks}	ε_{im} [11]
1	Alcohol & Tobacco	AT	0.431	0.433	-2.650	0.031	0	0.587
2	Food & Beverage	FB	0.058	0.392	-0.736	0.088	-0.289	0.662
3	Meat & Fish	MF	0.060	0.923	0.688	0.039	0	0.068
4	Clothing & Shoes	CL	0.172	0.100	-4.010	0.047	-0.574	0.205
5	Rent & Water	RW	0.046	0.362	0.575	0.215	-0.155	0.849
6	Electricity	EL	0.186	1.768	2.501	0.021	-0.900	1.158
7	Gas	GA	0.181	1.376	2.699	0.014	-0.463	0.319
8	Other fuels (heating)	FU	0.209	1.181	3.286	0.009	0	-0.161
9	Durables	DU	0.174	0.315	-1.609	0.050	0	1.462
10	Services	SE	0.152	0.127	-1.474	0.353	-0.484	1.334
11	Car Purchase	CP	0.169	0.194	1.177	0.055	-0.639	1.696
12	Car Use	CU	0.500	4.965	-3.602	0.072	-0.642	0.961
13	Public Transport	PT	0.057	0.202	-0.751	0.007	-0.172	0.250

[10] This is the scale elasticity of each commodity. Calculations are based on the procedure put forward in Schroyen (2010), see appendix E, $\sigma_j = \frac{s_j}{\alpha q_j}$.

[11] Income elasticity of each commodity.

Chapter 3

Inequality of opportunity in job quality achievement

co-authored by Elsy Verhofstadt and Luc Van Ootegem

3.1 Introduction

A good job is an important part of life: individual well-being, self-confidence and self-worth benefit from having a better job (Green (2006)). Like well-being, job quality is an inherently multidimensional concept. Income is surely one of its dimensions, but other aspects of a job should be taken into account as well, such as the autonomy or the stress experienced in the job. This makes the measurement of job quality difficult, as a weighting scheme is needed for its dimensions. In this article we solve this issue by using the distance function to measure job quality (see Lovell et al. (1994)). Our calculations will be based on five key dimensions of job quality proposed by Green (2006): income, skill utilization, work endeavour, personal discretion and risk. We investigate to what extent there is inequality of opportunity during the first year on the labour market and in the job at the age of 26. We use a questionnaire based dataset on labour market entry (SONAR) in Flanders, the northern part of Belgium. Besides information about individual characteristics of the respondents, the dataset contains information on their first job and their job at the age of 26.

There are several reasons why the quality of jobs matters from a public and welfare economic point of view. People spend a large part of their lives at work and what they do in their job is linked to who they are, as many people identify with the jobs they do. Furthermore, a better job increases future job perspectives and reduces the burden of working longer (see Clark (2005) or Green (2006)), which is a major challenge for many economies (Loughlin and Barling (2001)). It allows a person to be an active member of society and reduces the likelihood of criminal behaviour for young people (Allen and Steffensmeier (1989), Uggen (1999)). Hence there is considerable societal concern for equality of opportunity in the labour market (see e.g. Kalter and Kogan (2002, Khattab (2012), ILO (2012), Brynin and Güveli (2012)). For this reason, labour market agencies have been created in many countries to promote and facilitate high quality jobs for all citizens. One of their main concerns is equal access to the labour market and many of their efforts are especially aimed at young workers (ILO, 2012).

This article deals with equality of opportunity for multidimenional job quality of young workers. This consists of two separate issues: the first one is fairness in achieving job quality, the second issue is multidimensional job quality measurement. We deal with them one by one.

Ideas about fairness have been articulated in the equality of opportunity literature (see Dworkin

(1981a,b), Arneson (1989)), where a distinction is made between personal characteristics beyond the individual's responsibility, called circumstances, and characteristics the individual is responsible for, called efforts (Roemer (1998)). From an ethical point of view, inequality due to circumstances is considered objectionable, whereas inequality arising from differential efforts is morally acceptable. In our setting of labour market entry, the policymaker observes a specific distribution of job quality based on job characteristics in five dimensions. His aim is a society in which there is equal opportunity for job quality.

The measurement of opportunity inequality requires an answer to several methodological and empirical questions. Ramos and Van de gaer (2012) review the relevant issues and structure the existing literature based on a coherent framework[1]. The aim of our contribution is to measure to what extent observed inequality in job quality achievement is due to inter-individual differences in observed circumstances, and compare it with the findings in the literature. We compare the observed job quality inequality in the dataset with the inequality that would arise in the counterfactual situation in which circumstances were the same for all individuals, as in Bourguignon et al. (2007). The difference between the two can only be due to unequal opportunities. This means that we apply an indirect ex-post approach, which is concerned with outcome differences among individuals with the same circumstances. This choice is not without flaws –see Ramos and Van de gaer (2012) who argue in favour of a norm-based approach– but it is made because this is the most often used approach in the literature on income inequality. Inequality of opportunity in job quality achievement has not been studied before, so it is important to be able to compare with other findings in the literature.

[1] On the one hand, Ramos and Van de gaer (2012) distinguish between ex-ante and ex-post approaches. An ex-ante approach focuses on whether individuals have the same opportunity set, regardless of their circumstances, an ex-post approach is concerned with outcome differences among individuals with the same efforts but different circumstances. On the other hand, they distinguish between direct and indirect approaches, approaches based on stochastic dominance and norm-based approaches. In a direct approach the amount of inequality is calculated in the counterfactual situation where all effects efforts are eliminated, whereas an indirect approach focuses on the extent to which inequality is reduced if all effects of circumstances are eliminated. Both approaches can be applied in an ex-ante and an ex-post manner. The stochastic dominance approach is based on an ex-ante framework. It is concerned with comparing the cumulative distribution functions of income of individuals with different circumstances. If there is no first-order stochastic dominance between these cumulative distribution functions, there is no inequality of opportunity. The norm-based approach assigns to each individual a norm value for the output variable (e.g. income), as a function of circumstances and efforts. Then inequality of opportunity is calculated based on the distance between observed income with norm income.

A specific issue in the analysis of inequality of opportunity is the circumstances-efforts cut: which variables are to be considered as circumstances, and which variables are deemed efforts[2]. To some extent, this is a normative issue. In much of the literature, individuals are held responsible for the aspects of their life they can influence[3]. A practical solution is to perform sensitivity analysis with respect to the circumstances-efforts cut, this is what we will do as well. Sensitivity analysis is performed with respect to the circumstances-efforts cut in order to check the robustness of our results.

In line with Bourguignon et al. (2007), we take into account the fact that circumstances may have a direct and an indirect effect on job quality. The direct effects influence job quality directly, controlling for the impact of effort variables, but ignoring effects through them. They represent achievement differences that are completely beyond the individual's control. Indirect effects are effects through effort variables, for example an individual's own education level might be influenced by his parents' education level. This allows us to pay attention to the different channels through which circumstances influence job quality.

Now we deal with the second issue in this paper: how to measure multidimensional job quality? For the problem at hand, the planner observes a number of jobs with job characteristics in five dimensions. This multidimensional nature complicates issues, as multidimensional measurement entails important choices. The planner needs an evaluation instrument to compare these jobs, so a procedure is needed to summarize many dimensions into one measure of job quality. Several roads have been followed in the literature. One way to proceed is to use a fixed weighting scheme for the dimensions (equal weights, frequency based weights,...), but this is less attractive because it is hard to argue that the same weights should be used for all types of jobs implying that the trade-off between job characteristics is the same for all jobs. Moreover, how to determine the set of relative weights? This choice is always somewhat arbitrary, as it is hard for the planner to fix weights a priori. The advantage of this approach, however, is that it respects an attractive principle: the dominance principle[4] (see Decancq et al. (2011) and Schokkaert et al. (2011)).

[2]The most common factors beyond the individuals' responsibility in this literature are ethnicity, parental socioeconomic status and education level, and gender.

[3]Other ideas are prevalent as well, such as meritocratism. In a meritocratic view, individuals are held responsible for all personal factors, even their genetic endowment (Almas et al. (2011)).

[4]This principle requires that a job with better job characteristics in all dimensions has a higher job quality than a job with worse job characteristics in all dimensions.

In order to avoid the choice of arbitrary weights, a weighting scheme could be constructed based on the preferences of the individuals doing the job. This approach embodies 'respect for individual preferences', which is another attractive normative principle. Fleurbaey et al. (2009) have shown that the two principles, the dominance principle and respect for individual preferences, are incompatible. Hence, at least one of the principles has to be sacrificed. We decide to sacrifice the respect for individual preference principle and keep the dominance principle for the following reason. As the individuals in our sample are new to the labour market, they have little experience in judging the quality of a job and their preferences might reflect this lack of experience.[5] They have preferences, but these preferences might be ill-informed.

This has two implications. First, respecting individual preferences would imply that two individuals who are in the same 'objective' situation –they have the same circumstances, efforts and have the same job– might be judged differently in terms of job quality: their job quality differs if their preferences differ. As these two individuals have the same circumstances and arrive at the same job, we argue that, from an equality of opportunity point of view, they should be judged the same. Or, to put it in another way, the planner is interested in the distribution of job quality, irrespective of who has which job. The second implication is that we allow for some paternalism. To operationalize the framework, we rely on the so-called output distance function, which satisfies the dominance principle.

The output distance function is a concept commonly used in production economics to analyse firms' transformation process of inputs into outputs (see Deaton and Muellbauer (1980) or Coelli et al. (2005)). Lovell et al. (1994) have proposed to use the distance function for the measurement of well-being and it has been applied in a number of settings (e.g. Ramos and Silber (2005), Destefanis and Sena (2006)). The idea behind it is that individuals transform job characteristics in a number of dimensions into job quality. The achieved bundle of job characteristics is measured relative to a specific maximal attainable bundle of job characteristics. As such, our job quality measure is similar to a measure of efficiency. Job quality is expressed as a percentage: a job with the maximal attainable job characteristics has job quality equal to 1, or 100%. A job with only half of the maximal attainable job characteristics, has job quality of 0.5, or 50%. The consequence is that a job is considered better when it comes closer to a specific maximum,

[5]This argument holds in particular for the first job quality as in their job at the age of 26, individuals have gained some experience in judging job quality.

independent of the combination of job characteristics. More information about the distance function can be found in the next section.

The existing empirical literature on inequality of opportunity deals mostly with the achievement of one-dimensional outcomes such as income, health or educational attainment[6]. Our article contributes to this literature in two ways. First, empirical studies that focus specifically on inequality of opportunity in the job market or job quality achievement are scarce. Second, there is -to our knowledge- no contribution in this literature that deals explicitly with a multidimensional outcome variable. The aim of this article is to bridge this gap in the literature. The structure of the rest of the article is as follows. The next section deals with notation and the distance function. The estimation procedure is provided in section 3.3. Sections 3.4 and 3.5 contain the results and section 3.6 concludes.

3.2 Notation

School leavers (indexed $i = 1, ..., N$) enter the labour market. Each individual i has a vector of M individual characteristics $z^i = \left(z_1^i, ..., z_M^i\right) \in \mathbb{R}_+^M$ that are beyond his control such as gender, parental education level, unemployment rate upon labour market entry...[7] These are the individual's 'circumstances'. He has K job capacities $x^i = \left(x_1^i, ..., x_K^i\right) \in \mathbb{R}_+^K$ suited for the labour market (education level, job market experience, labour motivation...). The school leavers are (at least partly) responsible for these job capacities. In the rest of the article, the terms 'circumstances' and 'individual characteristics' on the one hand, and 'efforts' and 'job capacities' on the other hand, will be used interchangeably. Finally, in their jobs, they achieve a vector of L job characteristics $b^i = \left(b_1^i, ..., b_L^i\right) \in \mathbb{R}_+^L$ (income, autonomy...). The $L \times N$ matrix b contains the vectors b^i of all individuals.

There is a correspondence $B^i = B\left(z^i, x^i\right) : \mathbb{R}_+^M \times \mathbb{R}_+^K \to \mathbb{R}_+^L$, mapping individual characteristics and job capacities into achievable job characteristics. The set $B\left(z^i, x^i\right)$ contains all individual i's achievement vectors that can be realized with his input vectors z^i and x^i. In the process under analysis,

[6] See Ramos and Van de gaer (2012) for an overview of the literature on income inequality. Opportunity inequality in health is investigated by Rosa Dias (2009) or Trannoy et al. (2010). Brunello and Checchi (2007), Schütz et al. (2008) and Peragine and Serlenga (2008) investigate inequality of opportunity in educational attainment.

[7] Throughout the paper, individuals are indicated using superscripts, subscripts are used for categories of job capacities, job characteristics...

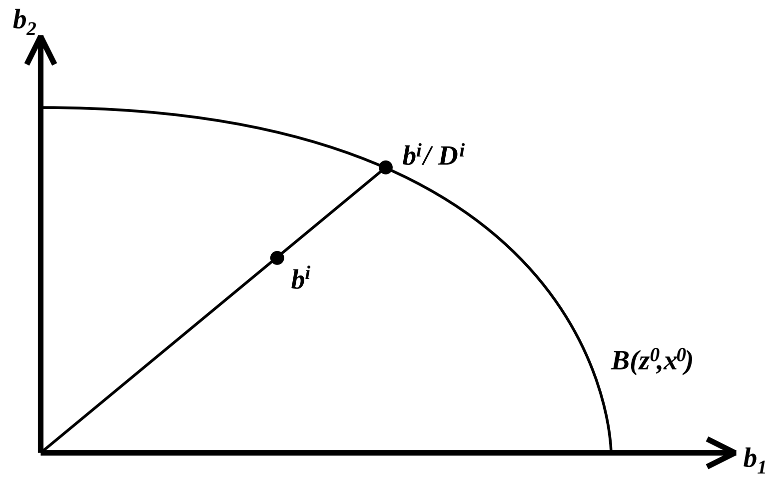
inputs (job capacities and individual characteristics) are transformed into outputs (job characteristics). The individual achieves one combination of job characteristics within his output set, $b^i \in B\left(z^i, x^i\right)$. For most individuals, b^i falls short of their maximal achievable job quality.

In this article, the output distance function is used to measure job quality. The better the job characteristics of a job, the higher the job quality should be, i.e. the dominance principle has to be fulfilled. In order to make job quality comparable over individuals, each job is compared with the same output set. This set is called $B\left(z^0, x^0\right)$, where it is assumed that each individual is endowed with z^0 and x^0, the most favourable situation in terms of individual characteristics and job capacities, respectively. This implies that the reference set $B\left(z^0, x^0\right)$ bounds all observations from above. The output distance function $D^i = D\left(z^0, x^0, b^i\right)$ is defined upon this output set as

$$D\left(z^0, x^0, b^i\right) = \min_d \left(d : \left(b^i/d\right) \in B\left(z^0, x^0\right)\right).$$

This is a measure between 0 and 1. It is the reciprocal of the factor by which all job characteristics could be increased while still remaining within the output set, see Figure 1.

Figure 1: The distance function



If an individual has a job characteristics vector on the boundary of the set, then the distance is equal to 1, or 100%. An individual with a vector of job characteristics inside $B\left(z^0, x^0\right)$ has a lower job quality, the distance will be below unity. All jobs with the same job quality as job b^i are assumed to be on the same distance from the output set[8]. The output distance will be our measure of job quality JQ^i, for an individual with job characteristics b^i,

$$JQ^i = D\left(z^0, x^0, b^i\right).$$

Job quality inequality means that JQ^i differs across individuals. The aim of this article is to investigate to what extent individual characteristics (z-variables) and job capacities (x-variables) play a role in achieving job quality and, based on this, to determine inequality of opportunity in job quality achievement

3.3 Estimation procedure

Information on the form of the reference output set $B\left(z^0, x^0\right)$ is generally not available. Often, the only solution is to rely on empirical information (Ramos and Silber (2005)), and this is also what we do. The output set we use below is based on the best performing individuals, those with a job characteristics bundle furthest from the origin in a specific direction. This means that we have to rely on the fact that the data contain enough and sufficiently diverse observations. The SONAR data we use contain 2512 randomly selected individuals entering the labour market.

There are several ways to estimate the distance function: it can be estimated both in a parametric and a nonparametric way. The parametric distance function was originally put forward by Lovell et al. (1994) and has been applied by Ramos and Silber (2005), who use the output distance function to measure individual well-being. This approach does not remain without problems, especially the fact that a specification needs to be chosen is vulnerable to criticism (Anderson et al. (2011))[9]. Therefore we use the nonparametric distance function, based on data envelopment (DEA) techniques. The results of the distance function are compared with the situation where income is taken as the only indicator of job quality.

[8]The output distance function is homogenous of degree one in outputs, non-decreasing and convex in outputs and decreasing in x and z (Coelli et al. (2005)). See Färe and Primont (2001) for a more detailed discussion of the properties of the distance function.

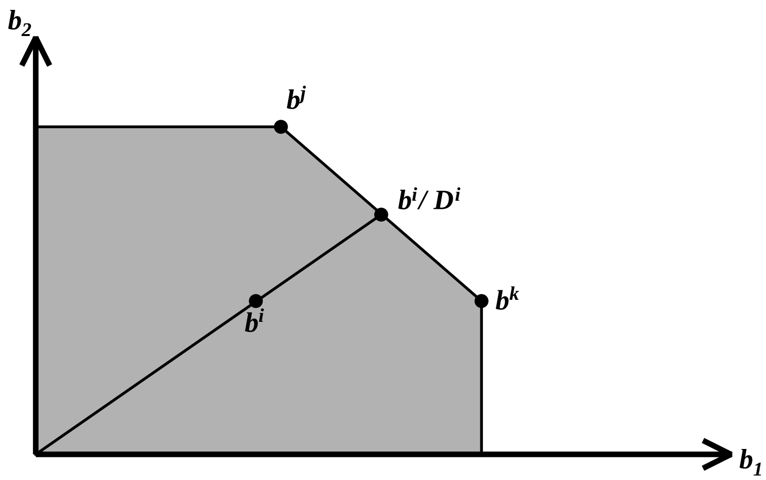
[9]The results of the parametric distance function estimation in panel data are available from the authors.

The estimation procedure consists of three steps. First, in section 3.3.1, the nonparametric distance function is estimated in order to measure each individual's job quality. In section 3.3.2, job quality inequality is measured. Job quality is regressed upon individual characteristics and job capacities. The amount of opportunity inequality is determined based on the reduction in inequality that would occur if all individuals had the same individual characteristics.

3.3.1 Nonparametric distance function

In data envelopment analysis, the boundary of the output set is determined based on the best performing individuals in terms of the dimensions of job quality. Figure 2 illustrates the approach with two individuals on the output set.

Figure 2: Data envelopment analysis



Three observations of job characteristics, b^i, b^j and b^k, are shown in the figure. The best-off observations are individuals j and k, so they are on the output set. In the figure D^i is the number by which all job characteristics have to be divided to reach the frontier; obviously $D^i \leq 1$. With superscripted t referring to the time period, we can define the job quality measures as:

$$JQ^{it} = D^{it}.$$

A linear combination of observations j and k is used to calculate the distance. In order to calculate job quality, linear programming techniques are used:

$$D^{it} = \underset{\lambda^{it}\geq 0, D^{it}\geq 0}{\arg\max} \begin{bmatrix} 0'_{2N} & 1 \end{bmatrix} \begin{bmatrix} \lambda^{it} \\ D^{it} \end{bmatrix} \text{ s.t. } \begin{bmatrix} -b & b^{it} \\ 1'_{2N} & 0 \end{bmatrix} \begin{bmatrix} \lambda^{it} \\ D^{it} \end{bmatrix} \begin{matrix} \leq \\ = \end{matrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

A vector λ with individual weights is calculated such that the distance from individual i's bundle to the linear combination of the job characteristics vectors of a number of other observations (those on the output set) is maximal[10]. The values of λ for individuals that are not on the output set are equal to zero.

3.3.2 Job quality inequality measurement

3.3.2.1 Counterfactual job quality and inequality measurement

To analyse inequality of opportunity, we compare the observed situation with the counterfactual situation in which all individuals are in the most favourable situation in terms of individual characteristics, z^0. To do this, estimated job quality is related to individual characteristics and job capacities, and then counterfactual job quality is calculated by putting the individual in the situation with reference individual characteristics. The most general job quality function can be written as

$$JQ^{it} = f\left(z^i, x^i, \mu^{it}\right),$$

with μ^{it} unobserved determinants. Now, job capacities might depend on individual characteristics: $x^i = x\left(z^i, c^i\right)$, with c^i unobserved determinants. This implies that the expression becomes:

$$JQ^{it} = f\left(z^i, x\left(z^i, c^i\right), \mu^{it}\right).$$

In this article, we use an indirect approach to inequality of opportunity measurement (as Bourguignon et al. (2007)). This means that we compare inequality in the observed sample with inequality in a counterfactual situation where all circumstances are set to reference levels, $z^i = z^0 \ \forall i$. Counterfactual job quality,

[10]Obviously, the optimisation is performed in five dimensional space, so generally more than two observations matter for the determination of the output set. Note that all jobs, from periods 1 and 2, are compared with the same output set.

taking into account the total effect of individual characteristics, can be calculated by filling in z^0 as $\widetilde{JQ^{it}} = \widehat{f}\left(z^0, x\left(z^0, c^i\right), \mu^{it}\right)$. Counterfactual job quality can also be calculated taking into account only the direct effects of individual characteristics, not the indirect effects through job capacities. Then we calculate $\widetilde{JQ^{it}}^d = \widehat{f}\left(z^0, x^i, \mu^{it}\right)$.

Inequality of opportunity can be analysed by calculating the difference in inequality between the distribution of JQ and $\widetilde{JQ}$. With I an inequality measure defined over both distributions, the inequality reduction[11] after all individual characteristics are equalized, is (see Bourguignon et al. (2007))

$$\Theta_I = \frac{I\left(JQ\right) - I\left(\widetilde{JQ}\right)}{I\left(JQ\right)}. \tag{1}$$

Based on $\widetilde{JQ}^d$, we can calculate $I\left(\widetilde{JQ}^d\right)$ and

$$\Theta_I^d = \frac{I\left(JQ\right) - I\left(\widetilde{JQ}^d\right)}{I\left(JQ\right)}. \tag{2}$$

This enables us to separate direct and indirect effects of individual characteristics. Intuitively, the measure

$$\Lambda_I = \frac{\Theta_I^d}{\Theta_I} \tag{3}$$

measures what percentage of total opportunity inequality is due to direct effects of individual characteristics differences.

3.3.2.2 Econometric specification

To construct the counterfactual, we use an econometric approach to get information on the specification of $f\left(z^i, x^i, \mu^{it}\right)$ and $f\left(z^i, x\left(z^i, c^i\right), \mu^{it}\right)$. Job quality is regressed upon job capacities and individual characteristics with OLS[12]:

$$JQ^i = \beta_0 + \sum_{l=1}^{M} \beta_l z_l^i + \sum_{j=1}^{K} \gamma_j x_j^i + \mu^i. \tag{4}$$

[11] The reduction of the inequality measure is expressed in relative terms in order to be able to compare our results with the existing literature.

[12] For ease of notation, superscript t is omitted.

The individuals can influence their job capacities, but not their individual characteristics. Individuals put forward effort to create job capacities, but these job capacities in turn are not independent of the individual characteristics (the individual's circumstances). Some individuals are in a more favourable position than others when they have more favourable individual characteristics, so there is also an indirect effect of individual characteristics on job quality, through job capacities. In order to separate both effects, each job capacity is regressed upon individual characteristics. For job capacity j we have

$$x_j^i = \beta_{0j} + \sum_{l=1}^{M} \beta_{lj} z_l^i + c_j^i, \tag{5}$$

with c_j^i the residual. The residuals of each of the job capacities regressions are considered as indicators of effort for each of the job capacities, as it is the part of job capacities that is not determined by individual characteristics taken into account, so for each individual there is a vector of job capacity efforts $c^i \in \mathbb{R}^K$. The remaining part of expression (5) is determined by the individual's characteristics. We plug in expression (5) in expression (4) to have

$$JQ^i = \beta_0 + \sum_{l=1}^{M} \beta_l z_l^i + \sum_{j=1}^{K} \gamma_j \left(\beta_{0j} + \sum_{l=1}^{M} \beta_{lj} z_l^i + c_j^i \right) + \mu^i,$$

which can be rewritten as

$$JQ^i = \varphi_0 + \sum_{l=1}^{M} \varphi_l z_l^i + \sum_{j=1}^{K} \gamma_j c_j^i + \mu^i, \tag{6}$$

where $\varphi_0 = \beta_0 + \sum_{j=1}^{K} \gamma_j \beta_{0j}$ and $\varphi_l = \beta_l + \sum_{j=1}^{K} \gamma_j \beta_{lj}$. With parameter estimates for expressions (4) and (6), we are able to determine the extent to which individual characteristics and job capacities contribute to job quality. Individual characteristics (z variables) influence job quality in two ways: there is a direct effect and an indirect effect through the job capacities (x variables). In the empirical section we will take a closer look at the difference between these two.

If we are interested in the total effect of individual characteristics on job quality, it suffices to estimate a reduced form of expression (6). Rewrite the expression as

$$JQ^i = \varphi_0 + \sum_{l=1}^{M} \varphi_l z_l^i + \eta^i, \tag{7}$$

with $\eta^i = \sum_{j=1}^{K} \gamma_j c_j^i + \mu^i$. This is the expression we use to determine the overall influence of the individual characteristics' on job quality inequality. Based on expression (7), counterfactual job quality, taking into account the total effect of circumstances, is calculated:

$$\widetilde{JQ^i} = \widehat{\varphi}_0 + \sum_{l=1}^{M} \widehat{\varphi}_l z_l^0 + \widehat{\eta}^i \tag{8}$$

In order to calculate counterfactual job quality, only taking into account the direct effect, expression (4) is used to calculate $\widetilde{JQ^i}^d$:

$$\widetilde{JQ^i}^d = \widehat{\beta}_0 + \sum_{l=1}^{M} \widehat{\beta}_l z_l^0 + \sum_{j=1}^{K} \widehat{\gamma}_j x_j^i + \widehat{\mu}^i. \tag{9}$$

If these counterfactual job quality estimates are used to calculate the opportunity share of job quality inequality, we are able to distinguish the differential impact of the direct and the indirect influences of individual characteristics on job quality inequality. Note that in the calculation of counterfactual job quality, the residuals of the regressions are used. As such they are considered as efforts, as in Bourguignon et al. (2007) and Björklund et al. (2012). We digress on this below.

3.4 Data

We use a survey database for Flanders (SONAR) that has been specifically created to study the transition from school to the labour market. This focus implies that it contains a mass of labour market information for school-leavers in their first work experience. We use the data of the birth cohort 1978, which was interviewed at the age of 23 and 26. The sample was randomly selected and trained interviewers performed the oral interviews at the 2512 interviewees' home address. The first job is defined as the first paid employment after leaving the educational system, with a job tenure of at least one month and for at least one hour a day and one day per week. For 1835 of the interviewees, there is information on their job at the age of 26 as well. After deleting missing observations, in total 3959 observations can be used in the estimations, 2310 for the first job and 1649 for the job at 26.[13] Summary statistics of the data are provided

[13]There are 686 individuals that are only observed in the first job and not in the job at 26. Only the education level differs significantly between the two samples, with 7.75 years for the first job and 7.96 years for the job at the age of 26 (see table A1 in appendix A). There is no significant difference between the other individual characteristics and job capacities in both groups, so the selection

in appendix A.

The information on job characteristics (b-variables) is in line with Green (2006): income, (lack of) risk, work endeavour, personal discretion (autonomy) and skill utilisation. Wage is a main determinant of labour supply and thus a key aspect of job quality. We use the log of net monthly income as the first job characteristic for all calculations below. The other four characteristics are based on self-assessment. The respondents were asked to evaluate 19 items on a 4-point scale, ranging from completely agree, rather agree, rather disagree to completely disagree. Using factor analysis this set is reduced to four variables that reflect the four non-monetary key factors as defined by Green (2006)[14]. More information on the 19 items can be found in appendix B. The second job characteristic is (the lack of) physically demanding work[15], it is an indicator of *risk* in Green's terminology. The third job characteristic, *work endeavour* measures whether there was time pressure in the job. The fourth job characteristic, *skill utilisation*, is based on answers to questions related to the challenge in the job, whether the respondent carried responsibilities, whether the tasks in the job were not repetitive etc. Finally, *personal discretion*, is based on questions related to the autonomy in the job. These job characteristics are observed twice: for the first job and for the current job.

There are in total 19 other variables providing information about the individuals. There are 13 variables that are -to a certain extent- under the control of the respondent (x-variables) and 6 variables that are beyond his control (z-variables). The x-variables can be split up in two categories: on the one hand characteristics related to the individual's experience or past: his education level, whether he was a member of a club, his search strategy... and on the other hand those characteristics that relate to his personality and his job motivation. In the first category there is educational attainment (number of successful school years after the age of twelve), the number of search channels or organisations that are used, the duration of the search period (i.e. the number of months between leaving education and starting in the first job) and five dummy variables: 'student work', 'apprenticeship', 'part-time school', 'having children' and 'club

bias is limited.

[14]We did a separate principal component analysis for every key feature identified by Green. Each time the items fitting with the key feature were included. The weights for the items are determined by factor analysis, see appendix B.

[15]Combination of responses of the questions: 'my first job demanded a lot of physical effort', 'I had to work in dangerous circumstances', 'I had to work in a dirty or smelly environment' and 'It was a job where I made myself or my clothes dirty'. This number is multiplied with -1 in order to make it a positive indicator of job quality.

membership'. The other job capacities belong to the second category: the impression the respondent makes on the interviewer, the job motivation variables and the 'locus of control' variables. The latter are based on the respondents' answers to questions related to their idea about who they think is responsible for their position in life. A factor score for 'locus of control internal' indicates whether respondents believe that they themselves are responsible for their achievements in life. A factor score for 'locus of control external' indicates whether the individuals believe that something or someone else is responsible for their achievements. There is also information (factor scores) on the degree to which the motivation to work results from the content of the job or from material aspects related to the job[16]. This list of efforts is broader than the lists used in the literature. In Bourguignon et al. (2007), only own education level, a dummy indicating whether an individual migrated to another region and the individual's labour market status are included, Pistolesi (2009) takes into account the individuals' education level and their labour supply (annual working hours).

The 6 variables beyond the individual's control (z-variables) are female, having a low educated mother, having a highly educated mother, having a non-Belgian grandmother and the regional unemployment rate at the moment that the respondent leaves school and enters the labour market. The sixth variable is a factor score containing information about the extent to which the respondent received information about employment possibilities at school, how to apply for a job, information about the official employment agency and about temporary employment agencies, information about local companies and vacancies and about job centres and information about self-employment[17]. These variables are used both in the first job and in the job after three years.

This list of circumstances differs from the lists used in the literature (see Ramos and Van de gaer (2013)). Björklund et al. (2012) use, apart from parental income and education level, information about family composition, IQ and body mass index as circumstance variables. Bourguignon et al. (2007) focus on parental education and occupation, race and region of birth in Brazil. As we are dealing with a small region (Flanders), the place of birth is less relevant. Regional differences in our analysis are captured by the regional unemployment rate at labour market entry. An extra circumstance in our model is whether or

[16]See appendix B for information on the questions used for each of the four variables and the calculation of the factor scores.

[17]Appendix B contains information on the calculation of the factor score.

not the individuals received information about the labour market at school.

3.5 Results

This section consists of three parts. First, the distance function estimation is analysed. Second, direct and indirect effects of individual characteristics (circumstances) are distinguished. Third, inequality due to individual characteristics is calculated. The results from the distance function are compared with an analysis based solely on income.

3.5.1 Job quality

The distance is calculated using linear programming in MATLAB. Summary statistics are provided in table 1. By definition, the maximum value for JQ is 100% because there are a number of individuals on the frontier, which is common for the two considered periods. Note that there are also individuals on the frontier in their first job.

Table 1: Summary statistics of income and job quality

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Mean	6.98	7.20	91.84	92.00
St.dev.	0.26	0.26	8.76	9.02
Min	4.82	5.00	55.90	55.40
Max	8.29	9.72	100	100

Note: $\ln(b_1)$ is the natural log of income, JQ is the measure of job quality.

Table 2 contains correlations and rank correlations between the measures. The correlations are rather low, the rank correlations are higher but still below 30%. This shows that it makes a difference to look at job quality in a multidimensional way, apparently the other job characteristics do not correlate strongly with income.

Table 2: Correlations and rank correlations between the measures

	JQ	
Correlations	1st job	At 26
$\ln(b_1)$	0.10	0.09
Rank correlations		
$\ln(b_1)$	0.24	0.28

Note: All correlations are significantly different from 0 at the 1% level.

3.5.2 Determinants of job quality

In this section we take a closer look at direct and indirect effects of individual characteristics on job quality achievement. The estimations are performed for the first job and the job at the age of 26 separately, in order to see differences between the two. The results of the estimation of expressions (7) and (4) are shown in tables 3 and 4 respectively.[18] We start with the total effects of circumstances in table 3.

Women achieve a lower income than men, both in their first job and in their job at the age of 26, where the effect is even stronger. At the same time, they achieve a higher job quality. Women compensate their lower income by achieving better scores on the other job characteristics. Especially the fact that they have jobs that are less physically demanding is worth noting[19]. One reason can be that women are not able to perform very physically demanding jobs and that men get extra compensation for performing them. Another reason could be that women might be more critical for jobs than men and that this is reflected in their search strategy[20].

As in Bourguignon et al. (2007) and Ferreira and Gignoux (2011), parental education plays a more important role than the other circumstance variables[21]. Individuals with a highly educated mother perform better in terms of job quality and those with a low educated mother perform worse. Finally, receiving information about work at school increases job quality and the unemployment rate at labour market entry

[18]The unemployment rate at labour market entry has a strong and negative influence on the job capacities. This is partly due to a cohort effect. Those individuals that started working at 18 entered the labour market at a considerably higher unemployment rate than those who started working later. As a consequence, the negative effect of the unemployment rate is due to two effects: a bad labour market situation (for which the individuals are not responsible) and a lower education level (entering the labour market at the age of 18, for which the individuals are partly responsible themselves). This is problematic because the effect of the unemployment rate should not depend on the individual's decisions. To remedy this, we regressed the unemployment rate on the residuals of the estimation of expression (5), with as dependent variable years of schooling (the residuals of the left-most column of table C1a). The residuals of this regression are used as indicator of the labour market situation at labour market entry (beyond the individuals' control).

[19]See tables C2a and C2b in appendix C, where each of the job characteristics is regressed on individual characteristics.

[20]This can be seen in table C1a in appendix C, where the fourth column shows that women tend to use more search channels (job capacity x_4) than men.

[21]In the literature, gender is often not taken into account. Bourguignon et al. (2007), Ferreira and Gignoux (2011) and Björklund et al. (2012) do not take into account gender. The first and the third study consider only male earnings, the second study deals with family income or consumption. As such, they avoids problems of comparability between men and women.

Table 3: Regression results with only circumstances

Expression (7)	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Female	-0.038***	-0.073***	2.917***	2.771***
Mother with low education	-0.047***	-0.044***	-1.117***	-1.326***
Mother with high education	0.081***	0.065***	1.622***	1.761***
Grandmother not belgian	-0.005	-0.005	0.178	-0.113
Info about work at school	-0.010*	-0.004	0.353**	0.193
U-rate at job market entry	-0.006**	0.000	-0.187**	-0.061
Constant	6.992***	7.230***	90.364***	90.586***
Sample size	2310	1649	2310	1649
Adj R squared	0.05	0.04	0.05	0.04

decreases job quality, but these two only play a role in the first job, the effects disappear mostly in the job at the age of 26. This suggests that entering the labour market in a bad situation might be difficult, but the effects are only temporary.

A part of the total effect of the individual characteristics in table 3 appears through the job capacities, this part is the indirect effect. Tables C1a and C1b in appendix C contain the job capacity estimations from expression (5). These results are relevant because they provide information on the channels through which circumstances determine efforts. They show to what extent the individual's job quality depends on circumstances directly and indirectly, via the job capacities. As he does not carry any responsibility for his circumstances, the individual is not held responsible for the direct effects. He is also not held responsible for the part of the job capacities that is determined by his circumstances. Indirect effects might compensate or exacerbate the direct effect.

Especially gender and the parental education level deserve attention. For example, girls study longer, make a better impression, are more interested in the content of the job and less in the material aspects of it, etc. All these have an influence on job characteristics and job quality, in turn. We compare the direct effects of individual characteristics from expression (4) in table 4 below with their total effect, from expression (7) in table 3.

In almost all cases, the coefficients with the circumstances in table 3 are larger in absolute value than in table 4, in line with the literature (see Bourguignon et al. (2007) and Ferreira et al. (2011) for income or Rosa Dias (2009) for health). This means that most circumstances influence job capacities in a such a way that they exarcebate the direct effect. For instance, having a low or highly educated mother negatively influences job quality in table 3. In table 4 it can be seen that most of the direct effects are not significant, so the total effect only appears through indirect effects. Apparently, mother's education level does not influence job quality directly, which is good news from an equality of opportunity point of view[22]. It only has an indirect effect through the build-up of job capacities[23].

The combined effect of the influences of circumstances on job capacities is that individuals with a highly educated mother achieve a higher job quality and individuals with a low educated mother achieve a lower job quality. Only in the case of the income level of women, the picture looks different. Judged by the direct effect, women have a 6.60% lower income than men, but an only 3.80% lower income judging by the combination of direct and indirect effects in table 3.

The direct effect of having a non-Belgian grandmother is positive for first job quality, though the effect disappears when the total effect is taken into account in table 3. Receiving information about the labour market at school only influences income in the first job. This might be due to the fact that, after they received information about the labour market, individuals focus less on income when looking for a job. Finally, we have a look at the coefficients of unemployment rate at labour market entry. In magnitude, the coefficients in tables 3 and 4 are similar, so indirect effects do not play a considerable role here. Some job capacities may depend on the unemployment rate at labour market entry, as can be seen in tables C1a and C1b, but positive effects compensate negative effects so the indirect effects of the unemployment rate on job quality are negligible.

3.5.3 Inequality of opportunity in job quality achievement

Now we have all the information to calculate counterfactual job quality and to compare observed job quality inequality in the sample with job quality inequality in the counterfactual situation where individual characteristics are the same for all individuals. First the analysis is performed with the six circumstances described above (the z-variables in table A1 in appendix A), then we perform sensitivity analysis by extending set of circumstances to incorporate the personality related job capacities[24], as they might also be considered to lie beyond the individual's responsibility.

[22] A significant direct effect could be seen as evidence that individuals use their parents' network to find better jobs, as noted by Peragine and Serlenga (2008).

[23] This is clearly visible in tables C1a and C1b. For instance, individuals with a highly educated mother study longer, are more motivated for the content of the job and less motivated for the material aspects of it, they make a better impression, etc.

[24] These job capacities are the impression the respondent makes during the interview (x_2), the job motivation variables x_6 and x_7, and the locus of control variables x_8 and x_9.

Table 4: Regression results circumstances and efforts

Expression (6)	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Female	-0.066***	-0.088***	1.940***	1.751***
Mother low edu	-0.014	-0.023	-0.399	-0.453
Mother high edu	0.024*	0.023	0.430	0.362
Grandm not belg	0.021	0.025	1.099*	0.523
Info about work	-0.014***	-0.003	0.200	0.103
U-rate at LM entry	-0.003	-0.002	-0.153**	-0.102
Schooling	0.046***	0.023***	0.844***	0.832***
Impression resp	0.005	0.014**	0.524***	0.562**
Club memb	0.003	0.002	-0.721**	0.036
Nr of search ch	-0.004**	-0.007***	-0.083	-0.036
Dur search	0.002***	0.003***	-0.008	-0.033
Job mot - cont	-0.009*	0.003	0.893***	0.933***
Job mot - mat	-0.013**	-0.011*	-0.298	-0.558**
Loc of contr int	0.002	0.007	0.018	0.350
Loc of contr ext	-0.002	0.006	0.167	0.091
Having childr	0.003	0.008	-1.114	-0.132
Studwork	-0.009	0.021	0.036	-0.132
Apprenticeship	-0.020*	-0.046***	-0.805**	-0.196
Part-time school	0.079***	-0.025	1.687*	0.342
Constant	6.668***	7.110***	85.384**	85.012***
Sample size	2310	1649	2310	1649
Adj R squared	0.15	0.10	0.10	0.10

Note: Significance at the 10%, the 5% and the 1% level is indicated with *, ** and *** respectively.

We use the procedures set out above to calculate counterfactual job quality. All individuals are put in a situation where they have ‘reference’ individual characteristics. This means that they are female, have a highly educated mother, have a Belgian grandmother at mother’s side, received information at school about work and entered the labour market in the best situation, at the lowest possible unemployment rate. The residuals are incorporated in the calculation of the counterfactual situation, so we consider the disturbance as a measure of effort. We use the Theil index as inequality measure[25].

Note that the adjusted R squared of the estimations is low[26]. This means that there is considerable variation in the data that is not explained by the circumstances and efforts that are taken into account in the model. This is not uncommon in the literature, e.g. Björklund et al. (2012) arrive at an adjusted R squared around 6%[27]. The residuals might capture, apart from noise, the influence of unobserved individual characteristics and job capacities, and luck. If more individual characteristics had been available in the data, measured inequality of opportunity increases. For this reason, we consider the estimates below as lower bounds on inequality of opportunity. With the available data, it is not possible to do better.

In table 5 inequality of opportunity measures are provided, for job quality and income. The first line in

[25] In the appendix, the calculations are performed with two other inequality measures: mean log deviation and the Gini coefficient. The results are broadly similar.

[26] This might be due to the fact that we consider the first job individuals have after leaving school.

[27] Their data contain only circumstances, no efforts. Their aim is to split up the error term in a circumstance-specific part (heteroskedasticity) and in noise.

Table 5: Inequality measurement

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Theil (observed)	0.0334	0.0437	0.0047	0.0050
Theil counterfactual (only z^0)	0.0317	0.0402	0.0042	0.0044
Theil counterfactual (z^0 and x)	0.0327	0.0420	0.0042	0.0046
Θ_I	4.80%	8.00%	14.89%	12.00%
Θ_I^d	1.80%	3.89%	10.64%	8.00%
$\Lambda_I = \frac{\Theta_I^d}{\Theta_I}$	37.54%	48.62%	71.44%	66.66%

the table contains the Theil index of observed job quality. The second and the third line contain the Theil index for counterfactual job quality. In the second line, only job characteristics are taken into account to calculate counterfactual job quality, so it is based on the results of table 3. Counterfactual job quality is based on expression (8). In the third line, counterfactual job quality is calculated based on the results of table 4. In this case, only the direct effects of individual characteristics are equalized and counterfactual job quality is calculated based on expression (9). Finally, Θ_I and Θ_I^d are provided from expressions (1) and (2), measuring with what percentage inequality would decrease if all individuals were in the reference situation in terms of individual characteristics. As such they are measures of opportunity inequality. The former measure takes into account the total effect of the equalization of opportunities, the latter measure takes into account only the direct effect of equalizing opportunities. The last line in table 5 is the ratio between Θ_I^d and Θ_I, based on expression (3). It measures what part of opportunity inequality is due to direct effects.

Now we have a look at the numbers in table 5. Job quality inequality is higher in the job at the age of 26 than in the first job, the Theil indices for the observed job increase for the three job quality measures. If only income is taken into account, only 4.80% of opportunity inequality in the first job is due to circumstance differences, and 8.00% in the job at the age of 26. This is a lower figure than in the existing empirical literature. In Bourguignon et al. (2007) circumstances account for between 10% and 37% of income inequality in Brazil for a large sample of men aged 26-60, Ferreira et al. (2011) find 26% to 31% opportunity inequality in Turkey[28], Ferreira and Gignoux (2011) reach numbers of roughly one fourth to a half in their analysis of income inequality in Latin America. Pistolesi (2009) arrives at around 30%-40% opportunity inequality in male earnings in the United States. Though international comparisons should be interpreted with caution, the difference with the existing literature is probably due to the fact

[28]The number depends on whether inequality in consumption or inequality in wealth is analysed.

Table 6: Inequality measurement with extra circumstances

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Theil (observed)	0.0334	0.0437	0.0047	0.0050
Theil counterfactual (only z^0)	0.0312	0.0400	0.0036	0.0042
Theil counterfactual (z^0 and x)	0.0324	0.0423	0.0041	0.0044
Θ_I	7.37%	8.53%	23.40%	16.90%
Θ_I^d	2.94%	3.11%	12.35%	11.70%
$\Lambda_I = \frac{\Theta_I^d}{\Theta_I}$	39.89%	36.46%	52.78%	69.23%

that our sample is rather homogenous. The individuals just entered the labour market and have the same age, so income differences are lower than if income inequality is measured across ages.

For the job quality JQ, the Theil indix decreases with a higher percentage if inequality due to circumstances is eliminated. Inequality of opportunity as judged by the two other job quality measures is similar in the first and the second job, around 12-15% of inequality is due to differences in individual characteristics. It clearly makes a difference to look at job quality in a multidimensional manner for judgements of opportunity inequality. If only income is taken into account, opportunity inequality is underestimated.

Finally we deal with the difference between direct and indirect effects of circumstances. Around 70% of the opportunity inequality in JQ is due to direct effects. This is in line with the empirical literature, see i.a. Bourguignon et al. (2007), who find that the direct effect contributes to around 60% of opportunity inequality in income[29]. Note that though inequality as a whole goes up at the age of 26, the opportunity share of job quality inequality remains the same.

Now we perform some sensitivity analysis with respect to the circumstances-efforts cut. We focus on what would happen if the definition of circumstances is broadened so that it encompasses personality traits as well. More specifically, the impression the respondent makes (x_2), the job motivation variables (x_6 and x_7) and the locus of control variables (x_8 and x_9) could be considered to lie beyond the individuals' responsibility. Appendix E contains the estimations of expression (7) with the five extra circumstances.

Table 6 tabulates the results of the sensitivity analysis. The measures of inequality of opportunity increase, while the direct opportunity share in the case of first job quality decreases, as compared to the results in table 5. The latter observation suggests that the five extra circumstances influence first job quality mostly via indirect effects -their effects on the remaining job capacities.

[29]Note here the difference with the results of the Gini coefficient and the MLD in appendix D. The size of the direct effects of circumstances on opportunity inequality in income are more sensitive for the type of inequality measure chosen.

3.6 Conclusions

This article deals with job quality measurement and with inequality of opportunity at labour market entry in the first job individuals find and in their job at the age of 26. One problem with the measurement of job quality is the fact that there are several job characteristics that have to be weighted in some way. In this article we follow Ramos and Silber (2005), we use the output distance function to determine the weights of five job characteristics put forward by Green (2006). The advantage of the approach is that the weights attached to the job characteristics can differ across jobs and that individuals with the same job are judged equal in terms of job quality. Job quality based on the distance function is compared with inequality in the incomes individuals get in their jobs.

Job quality depends on individual characteristics and the individual's job capacities. The individual is held responsible for the latter, but not for the former. In the empirical section, we investigate how circumstances influence job quality. The most important circumstance variables are gender and parental education. The labour market situation at job market entry only influences the quality of the first job, not the quality of the job at the age of 26. We separate out direct and indirect effects of individual characteristics on job quality and observe that the indirect effects play a considerable role.

Concerning the effects of individual characteristics, one important result is that women have a lower income, but compensate this with a higher score on other job characteristics, e.g. they have a physically less demanding job. Taken together, women achieve jobs with higher job quality. The direct effect of the dummy female is positive, and on top of that, women build better job capacities: they study longer, make a better impression, are more motivated for the content of the job... All these indirect effects improve on the already positive direct effect. The mother's educational level plays an important role as well, but in a slightly different way. Individuals with a low educated mother find jobs with worse job characteristics in all dimensions and those with highly educated mothers find jobs with better characteristics in all dimensions. Here, there is no direct effect, there are only effects through job capacities. For instance, individuals with a low educated mother study less, are less motivated for the content of the job, make a worse impression... All these influence job quality indirectly.

The results regarding inequality of opportunity are that job quality inequality increases over time for all job quality measures, but the magnitude of inequality of opportunity remains the same. Inequality of opportunity is measured as the percentage the inequality index decreases if the individuals are put in a counterfactual situation in which circumstances are equal for all. Income inequality decreases with about 5% if all circumstances are equalized and this percentage is slightly higher in the job at the age of 26. Between 12% and 14% of the observed job quality inequality is due to differential circumstances. A bit less than half of this percentage is due to the direct impact of circumstance differences, the remainder is due to indirect effects via job capacities.

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Appendix A: Data and job quality measures

Table A1: Individual characteristics and job capacities

	First job			Job at the age of 26		
Variable name	Avg.	Min.	Max.	Avg.	Min.	Max.
b_1 wage	1107.36	123.95	4000.00	1383.48	148.00	16600.00
b_2 risk (physically demanding work)	5.00	2.35	6.15	5.00	2.56	6.21
b_3 work endeavour	4.73	2.95	6.21	5.00	2.95	6.21
b_4 skill utilisation	5.00	2.49	6.71	5.00	0.79	6.56
b_5 personal discretion (autonomy)	5.00	3.59	7.02	5.00	2.97	6.67
z_1 gender (dummy female=1)	0.50	0	1	0.49	0	1
z_2 mother low education (dummy)	0.34	0	1	0.33	0	1
z_3 mother high education (dummy)	0.25	0	1	0.26	0	1
z_4 grandmother not Belgian (dummy)	0.08	0	1	0.07	0	1
z_5 info about work during education	0.00	-1.66	1.54	0.00	-1.66	1.54
z_6 u-rate at job market entry	8.67	3.54	17.58	8.55	3.54	17.58
x_1 schooling (years)	7.75	1	14	7.96	1	14
x_2 impression respondent	0.03	-4.83	6.08	0.08	-4.51	6.08
x_3 club membership (dummy)	0.56	0	1	0.53	0	1
x_4 number of search channels	3.80	0	14	3.78	0	14
x_5 duration of search period	5.27	1	103	5.27	0	103
x_6 job motivation - content	0.00	-3.78	2.31	0.00	-4.36	2.64
x_7 job motivation - material	0.00	-3.77	2.94	0.00	-3.01	4.07
x_8 locus of control internal	0.00	-3.21	2.40	0.00	-2.99	2.52
x_9 locus of control external	0.00	-3.04	2.45	0.00	-3.53	2.82
x_{10} having children (dummy)	0.03	0	1	0.19	0	1
x_{11} student work (dummy)	0.79	0	1	0.80	0	1
x_{12} apprenticeship (dummy)	0.67	0	1	0.67	0	1
x_{13} part-time school (dummy)	0.08	0	1	0.07	0	1

Appendix B: Factor analysis

This appendix contains information on the construction of the job characteristics, the locus of control variables and the job motivation variables. Respondents were asked to answer 19 questions on a four point scale (completely disagree, rather disagree, rather agree, completely agree). Job characteristics 2, 4 and 5 are based on the answers to these questions using factor analysis. The third job characteristic is based on the answer to one question: I had to work at a high pace or under time pressure.

Table B1: Risk (physically demanding work)

Items for b_2	Component
My first job demanded a lot of physical effort	0.718
I had to work in dangerous circumstances	0.733
I had to work in a dirty or smelly environment	0.769
It was a job where I made myself or my clothes dirty	0.835

Table B2: Skill utilisation

Items for b_4	Component
My job demanded a lot of mental effort	0.609
My job demanded creative ideas	0.745
I carried a lot of responsibilities	0.666
It was a job I saw the results of	0.611
It was a job where I could show what I was capable of	0.797
It was a job where I had to cooperate with others	0.330
It was a job where I always had to do the same things	-0.641
It was a job where I could endulge myself	0.755
I regularly had to study for my job	0.845
My job was challenging	0.835
I did things in my job that were worth doing	0.650

Table B3: Personal discretion (autonomy)

Items for b_5	Component
I could decide in which way I did my work	0.817
I could decide how much work I did in one day	0.875
I could decide which work I did in one day	0.872

The individual characteristic 'information about work during education' is based on the answers to 6 questions, on a four point scale (completely disagree, rather disagree, rather agree, completely agree).

The job motivation variables are based on seven questions, on a four point scale (completely disagree, rather disagree, rather agree, completely agree). They are summarised in tables B5 and B6.

Finally, there are two locus of control variables: locus of control internal and locus of control external. They are based on four variables on a four point scale (completely disagree, rather disagree, rather agree, completely agree).

Table B4: Info about work during education

Items for z_5:	Component
At school I got information about...	
writing letters and cv	0.606
the VDAB (public employment service)	0.653
companies, employment agencies,...	0.755
job advertisements	0.757
job fairs	0.513
being self-employed	0.545

Table B5: Job motivation - content

Items for x_6	Component
Working gives you the feeling to do something useful	0.662
One works mainly in order to do interesting things	0.818
One works mainly in order to do creative things and have new ideas	0.790

Table B6: Job motivation - material

Items for x_7	Component
One works mainly to make money	0.712
It is better to accept any job than to be unemployed	0.583
The type of work is not important, as long as one makes money	0.685
One works mainly to have security and stability in life	0.625

Table B7: Locus of control internal

Items for x_8	Component
If you don't make progress in life, it is your own responsibility	0.792
Succes in your job is a matter of hard work, luck only has minor influence	0.792

Table B8: Locus of control external

Items for x_9	Component
Most of the bad things happen without that you have an influence on them	0.767
Whether or not you get a good job depends on accidentally being at the right place at the right moment	0.767

Appendix C: Regression results individual characteristics and job quality

Table C1a

Expression (5)	x_1	x_2	x_3	x_4	x_5	x_6	x_7
z_1 gender (dummy female=1)	0.848***	0.167***	-0.170***	0.401***	0.480	0.237***	-0.187***
z_2 mother low education (dummy)	-0.710***	-0.206***	-0.069***	-0.033	1.338***	-0.011	0.244***
z_3 mother high education (dummy)	1.480***	0.047	0.155***	0.338**	-1.356***	0.145***	-0.265***
z_4 grandmother not belgian (dummy)	-1.090***	-0.003	-0.074**	-0.132	5.361***	-0.190**	-0.036
z_5 info about work during education		0.037*		0.107*	-0.339**	0.088***	0.022
z_6 u-rate at job market entry		0.004		-0.062***	-0.807***	0.006	0.031***
Constant	7.295***	0.009	0.631***	3.541***	4.482***	-0.135***	0.080**
Sample size	2510	2510	2510	2510	2510	2510	2428
Adj R^2	0.19	0.02	0.06	0.01	0.08	0.03	0.06

Table C1b

Expression (5)	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
z_1 gender (dummy female=1)	-0.220***	-0.007	0.003	0.058***	0.215***	-0.054***
z_2 mother low education (dummy)	0.078*	0.107**	-0.005	-0.082***	-0.003	0.023*
z_3 mother high education (dummy)	-0.027	-0.148***	-0.010	0.087***	-0.024	-0.054***
z_4 grandmother not belgian (dummy)	0.110	-0.087	0.005	-0.152***	-0.157***	0.076***
z_5 info about work during education	0.042**	0.025				
z_6 u-rate at job market entry	0.005	0.009				
Constant	0.080**	0.011	0.028***	0.781***	0.585***	0.102***
Sample size	2497	2497	2510	2510	2510	2510
Adj R^2	0.02	0.01	0.00	0.04	0.06	0.03

Note: Significance at the 10%, the 5% and the 1% level are indicated with *, ** and *** respectively. The unemployment rate at labour market entry is only taken into account when it is relevant.

For each of the job characteristics, the specification is

$$b_m^i = \alpha_{0m} + \sum_{l=1}^{M} \alpha_{lm} z_l^i + \eta_m^i, \qquad \text{(C1)}$$

estimated with OLS. The results of these regressions are provided in tables C2a and C2b.

Table C2a: Job characteristics estimations – first job

Expression (C1) for first job	$\ln(b_1)$	b_2	b_3	b_4	b_5
Female	-0.038***	0.412***	-0.012	0.044	0.041
Mother with low education	-0.047***	-0.133***	-0.047	-0.133***	-0.172***
Mother with high education	0.081***	0.222***	-0.001	0.185***	0.222***
Grandmother not belgian	-0.005	-0.121*	0.039	-0.134*	-0.085
Info about work at school	-0.010*	0.053***	-0.023	0.072***	0.059***
U-rate at job market entry	-0.006***	-0.042***	0.012	-0.022**	-0.030***
Constant	6.992***	4.780***	4.753***	4.989***	4.992***
Sample size	2310	2310	2310	2310	2310
Adj R squared	0.05	0.09	0.00	0.03	0.04

Table C2b: Job characteristics estimations – job at the age of 26.

Expression (C1) for job at the age of 26	$\ln(b_1)$	b_2	b_3	b_4	b_5
Female	-0.073***	0.484***	-0.004	-0.020	0.082*
Mother with low education	-0.044***	-0.277***	-0.076	-0.160***	-0.138**
Mother with high education	0.065***	0.211***	0.111*	0.199***	0.270***
Grandmother not belgian	-0.005	-0.140	0.003	-0.092	-0.087
Info about work at school	-0.004	0.018	0.023	0.044*	0.009
U-rate at job market entry	0.000	-0.031***	0.014	0.001	-0.028***
Constant	7.230***	4.808***	4.995***	5.016***	4.941***
Sample size	1649	1649	1649	1649	1649
Adj R squared	0.04	0.12	0.00	0.02	0.04

Appendix D: Inequality measurement using Gini coefficient and Mean Log Deviation

This appendix contains inequality calculations based on two other inequality measures put forward in the literature: the Gini coefficient and Mean Log Deviation (MLD).

Table D1: Inequality measures with Gini coefficient

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Gini (observed)	0.1324	0.1289	0.0562	0.0584
Gini counterfactual (only z^0)	0.1288	0.1251	0.0503	0.0491
Gini counterfactual (z^0 and x)	0.1315	0.1254	0.0525	0.0534
Θ_I	2.75%	2.91%	10.57%	15.87%
Θ_I^d	0.74%	2.66%	6.65%	8.62%
$\Lambda_I = \frac{\Theta_I^d}{\Theta_I}$	26.90%	91.41%	61.59%	54.31%

Table D2: Inequality measurement based on Mean Log Deviation

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
MLD (observed)	0.0334	0.0362	0.0048	0.0052
MLD counterfactual (only z^0)	0.0317	0.0341	0.0043	0.0046
MLD counterfactual (z^0 and x)	0.0327	0.0349	0.0045	0.0048
Θ_I	5.06%	6.05%	10.66%	11.90%
Θ_I^d	2.02%	3.65%	6.79%	8.35%
$\Lambda_I = \frac{\Theta_I^d}{\Theta_I}$	39.93%	60.34%	63.70%	69.65%

Appendix E: Inequality measurement with personality traits as circumstances

Table E1: Job quality regression results with only individual characteristics in reduced form.

Expression (7)	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Female	-0.048***	-0.084***	2.271***	2.314***
Mother with low education	-0.032***	-0.040***	-0.712*	-1.150**
Mother with high education	0.073***	0.054***	1.270***	1.293**
Grandmother not belgian	-0.005	0.010	0.546	0.044
Info about work at school	-0.009*	-0.003	0.230	0.300
U-rate at job market entry	-0.005**	0.000	-0.160**	-0.058
Impression respondent	0.014**	0.021***	0.672***	0.726***
Job motivation - content	0.005	0.007	1.137***	1.044***
Job motivation - material	-0.038***	-0.024***	-0.738***	-0.982***
Locus of control external	-0.003	0.003	-0.107	0.178
Locus of control internal	-0.005	0.002	0.101	-0.056
Constant	6.995***	7.235***	90.620***	90.885***
Sample size	2310	1649	2310	1649
Adj R squared	0.07	0.06	0.08	0.08

Table E2: Inequality measurement with three extra circumstances

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
Gini (observed)	0.1324	0.1289	0.0562	0.0584
Gini counterfactual (only z^0)	0.1269	0.1248	0.0483	0.0504
Gini counterfactual (z^0 and x)	0.1308	0.1246	0.0496	0.0512
Θ_I	4.49%	3.18%	14.06%	13.70%
Θ_I^d	1.21%	3.34%	11.74%	12.33%
$\Lambda_I = \frac{\Theta_I^d}{\Theta_I}$	26.95%	105.03%	83.50%	90.00%

Table E3: Inequality measurement with three extra circumstances

	$\ln(b_1)$		JQ	
	1st job	At 26	1st job	At 26
MLD (observed)	0.0334	0.0362	0.0048	0.0052
MLD counterfactual (only z^0)	0.0311	0.0338	0.0039	0.0043
MLD counterfactual (z^0 and x)	0.0324	0.0335	0.0042	0.0046
Θ_I	6.82%	6.76%	19.08%	17.91%
Θ_I^d	3.00%	7.46%	12.79%	12.35%
$\Lambda_I = \frac{\Theta_I^d}{\Theta_I}$	43.95%	110.42%	38.39%	69.23%

Chapter 4

Measuring individual well-being and poverty using equivalent income and self-reported possibilities

4.1 Introduction

Evaluating well-being and comparing it across individuals is a difficult exercise. How to compare, for instance, a poor individual in good health with an individual in a worse health situation, but with a high income level? It has been argued that the individuals' own judgment about their life should be taken into account in some way, i.e. their preferences between health and income should be respected (Fleurbaey et al. (2009), Fleurbaey and Blanchet (2013)). People are assumed to have 'true underlying preferences', but these are hard to measure (McQuillin and Sugden (2012)). For measuring well-being, information on preferences is usually derived from self-reported satisfaction with life or happiness[1]. But satisfaction is arguably not the only thing that matters, and problems have been reported with its measurement (Fleurbaey and Blanchet (2013)).

McQuillin and Sugden (2012) argue that it could be interesting to identify another object of value, assign normative value to it, and try to measure it to obtain information on preferences. The aim of this paper is exactly this. We investigate whether information on preferences can be derived from the concept 'self reported possibilities'[2] and whether it can overcome some of the problems associated with satisfaction measurement. We calculate equivalent income, as proposed by Fleurbaey et al. (2009), based on satisfaction and on possibilities, and compare it with four other measures: family income, family income corrected for family size, self-reported satisfaction and self-reported possibilities. We use a questionnaire conducted in Flanders (Belgium) containing extensive information on individuals' lives. We investigate who is considered poor in each of the measures.

The next section discusses the measurement of true underlying preferences. The concept of self-reported possibilities is introduced and discussed. Section 4.3 and 4.4 deal with notation and the data. Section 4.5 contains the results and section 4.6 concludes.

[0]I would like to thank Luc Van Ootegem and Elsy Verhofstadt for providing me with the data and Dirk Van de gaer and Erik Schokkaert for valuable comments on earlier versions of this paper.

[1]Both the terms happiness and satisfaction are used in the literature. In this paper, we stick with the term (life) satisfaction, as this is the term used in our questionnaire.

[2]Self-reported possibilities are the possibilities people have today to pursue whatever they strive for.

4.2 Preferences and well-being

It is well-established in the literature that well-being is a firmly multidimensional concept (see e.g. Stiglitz et al. (2009), Helliwell (2012)). A life is then described in terms of the achievement of functionings[3] in a number of dimensions, such as health or material living standards. To arrive at an overall measure of well-being, a synthetic index needs to be calculated with trade-offs between the different dimensions.

There are several ways to translate many dimensions into one. One way is to determine a priori weights for the dimensions (see Decancq and Lugo (2013) for an overview), another way is to rely on the distance function (see Ramos and Silber (2005) or Defloor (2013)). In these approaches, however, the weights are not based on the judgments of the individuals themselves, which renders these approaches paternalist. Fleurbaey and Blanchet (2013) argue that there is a general consensus in the literature that, in some form, people's own judgments should be the ultimate guideline in the evaluation of their well-being. Fleurbaey et al. (2009) proposed a theoretically attractive approach to do this: the equivalent income approach, which we use in this paper. Equivalent income is the level of income that, given reference values for the other dimensions of functionings, makes an individual indifferent to his actual situation.

In order to calculate equivalent income, information on individual preferences is needed, which is not easy to obtain. In the literature, this information is usually distilled from an overaraching evaluation question where individuals are asked to evaluate their well-being in some way, and econometric techniques are used to derive information on preferences. In the satisfaction literature, well-being is usually measured by individual life satisfaction. The life satisfaction question in our questionnaire is standard and formulated as "How satisfied are you with your life as a whole, on a scale from 0 (completely insufficient) to 10 (excellent)".

Two problems are associated with this cardinalisation of preferences. The first problem is related to the physical condition neglect of satisfaction information (Sen (1980 and 1985)): the mental state of the individual does not say anything per se about his physical condition. People may adapt their aspirations to their life situation and state to be relatively satisfied when they are income poor or in bad health.[4] The

[3]The term functionings is due to Sen. A funtioning is conceptualized as his doings or beings in a specific dimension of life.

[4]As argued in Fleurbaey et al. (2009), pleasure is not always good, and displeasure is not always perceived as something bad. Some sources of pleasure are disliked, whereas there are types of dissatisfacion that relate to the value of important aims in life still to be

second problem has to do with the fact that the answers people provide to the self-reported satisfaction question are a mixture of two things: a cognitive judgment –what people think of their life– and an affective judgment –how people feel in their life (Fleurbaey and Blanchet (2013)). Information on true preferences should be based on the former, not on the latter, as affective information might be influenced by moods –which are typically short-lived.

Consequently, in order to get information on true underlying preferences –the cognitive judgment individuals make about their lives, aspirations and affective judgments need to be filtered from the life satisfaction information. Equivalent income does this. Empirically, a number of variables are associated with aspirations and affects, and their direct effects on life satisfaction are left out of consideration in the calculation of equivalent income. To the extent that aspirations and affects are captured by the direct effects of these variables, equivalent income respects individuals' cognitive evaluation of their lives. This is an empirical matter.

If an overarching evaluation question can be found that is less dependent on aspirations and affects, then it might provide clearer information on the individuals' true underlying preferences, as no correction is needed. Fleurbaey and Blanchet (2013) argue that there are other things that people value, apart from life satisfaction. They note that, even if satisfaction were the only aspect of life that is relevant, and all other aspects had some impact on satisfaction, this would not prove that the other aspects of life are also not partly desirable for themselves[5].

The concept we focus on in this paper is based on how individuals perceive the possibilities they have today to whatever they want. An individual's functionings achievement contributes to his possibilities, e.g. someone with a better health or a higher income might have more possibilities, he is more able to pursue the things he wants. Someone with a low income might be inhibited to pursue the things he wants. This is how we interpret the second overarching question we take into account to get information on preferences. The self-reported possibilities question in our questionnaire goes as follows: "How are the possibilities for you, in general, on a scale from 0 (completely insufficient) to 10 (excellent)". This question refers to

accomplished.

[5]They give the example of health: the fact that health is directly desired does not imply that people only want a good health for the purpose of being happy or satisfied. They also note that the effect on satisfaction of some of the things people strive for is unsure, e.g. people aim for having a diploma, but the effect of being higher educated on satisfaction is unsure and might well be negative.

the possibilities today, it is the last question of a list of ten aspects of possibilities from the survey we use from Van Ootegem and Verhofstadt (2013)[6] (see appendix A). This is also a cardinalisation of preferences and an alternative source of information on preferences. There are reasons to assume that self-reported possibilities are less biased by aspirations and affects. Especially the framing of the question matters.

Fleurbaey and Blanchet (2013) devote specific attention to the framing of the overarching question. They identify three problems with which the respondent is confronted when answering questions of the types stated above: (1) the scope problem –which part exactly of life is relevant, (2) the ranking problem –how does the life stand in the set of relevant possible lives– and (3) the calibration problem –how does the position in the ranking translate into a number between 0 and 10. In order to resolve the first two problems, they suggest to pay specific attention to the order of the questions and the framing in the questionnaire. Ambiguity of scope is likely to create uncontrolled diversity across individuals, and thus more noise in the answers. The ranking problem has to do with the cognitive complexity of putting the multidimensional nature of life into an ordinal scale. When confronted with this difficulty, respondents might be induced to avoid the question and consider whether their mood of the day or other salient aspects of life provide informative information, and forget relevant aspects of life. If the evaluative question is asked after a comprehensive list of dimensions of life, the scope problem and the ranking problem are somewhat reduced, as the relevant dimensions of life are brought in mind of the respondent[7]. The third problem –the calibration problem– is harder to resolve. The respondent must choose a benchmark with which to compare their life. There are several options, such as the individual's own life experience, the lives of other people etc. This introduces a source of heterogeneity across individuals. We do not pay specific attention to this issue here, we assume that the heterogeneity is taken up by the residuals in the estimations below.

We argue that our self-reported possibilities question might provide better information on the cognitive judgment of an individual's life for two reasons. First, we argue that self-reported possibilities are less vulnerable to the influence of affects than self-reported satisfaction. The reason for this is that satisfaction

[6] Individuals are asked to rate their possibilities today, to find happiness, to live a healthy life, to have access to education, to decide the direction of life, to have enough income, etc...

[7] Comparability across individuals is enhanced too. They all have answered the same questions and so when they answer the overarching question, their scope is more similar.

or happiness are important aims in life for many people and they are often the subject of societal debate. Consequently, individuals might feel the need or the duty to state to be relatively satisfied, even if their living conditions are miserable. Moreover, happiness and satisfaction refer more to feelings than the extent to which people have possibilities to pursue whatever they want. As a consequence, the answers to the satisfaction question might be more guided by a judgment about their affects than by a cognitive judgment about their lives. The extent to which individuals have possibilities is much less debated, so individuals might have to think more deeply about the possibilities question. Their mood of the day or other salient aspects of life are less informative for answering this question. Consequently, their answers might reflect closer their cognitive evaluation of their lives.

The second reason has to do with the framing of the possibilities question in our survey. Before answering the possibilities-in-general question, individuals are asked to answer ten questions about their possibilities in a number of dimensions of life –see appendix A. As a consequence, the scope of the question is clear and it is the same for all respondents. For this reason, we argue that the answers to the possibilities question provide a more focused picture than the satisfaction question, which in our survey is asked without reference to a specific frame. This implies that we expect that answers to the possibilities questions contain less noise than the answers to the satisfaction with life question.

In the empirical section, we investigate how the achievement of functionings in a number of dimensions of life contributes to satisfaction and to possibilities. From this, information on preferences is derived. To do this, we use the list of eight dimensions of functionings provided in the Stiglitz-Sen-Fitoussi report[8] (Stiglitz et al. (2009)). We use the LEVO dataset, where a sample of the flemish population is surveyed (see Van Ootegem and Verhofstadt (2013)).

4.3 Notation and criteria

There are N individuals, indexed $i = 1, ..., N$. Each individual i achieves a vector of M functionings $f^i = \left(f^i_1, ..., f^i_M\right) \in \mathbb{R}^M_+$, his individual beings and doings in M life domains. The individual's family income is $y^i_f \in \mathbb{R}_+$ and adjusted income $y^i_a \in \mathbb{R}_+$ is family income divided by the square root of the

[8]These dimensions are (i) material living standards, (ii) health, (iii) education, (iv) personal activities including work, (v) political voice and governance, (vi) social connections and relationships, (vii) environment and (viii) physical and economic security.

family size. Individual i has K individual characteristics, represented by the vector $x^i = \left(x_1^i, ..., x_K^i\right) \in \mathbb{R}_+^K$. These are demographic variables such as gender, age, having children, the number and the age of the children,... Each individual has L personality traits, the vector $t^i = \left(t_1^i, ..., t_L^i\right) \in \mathbb{R}^L$. The individual's reported level of satisfaction is $s^i \in \mathbb{R}_+$ and his self-reported possibilities are represented by $p^i \in \mathbb{R}_+$. Individual i's mood of the day is $m^i \in \mathbb{R}_+$.

Let R^i be a binary relation on (f, y), interpreted as individual i's preference ordering. The statement $\left(f^i, y^i\right) R^i \left(f^{i\prime}, y^{i\prime}\right)$ means that $\left(f^i, y^i\right)$ is considered at least as good as $\left(f^{i\prime}, y^{i\prime}\right)$ from the point of view of individual i. Let A^i denote the individual's aspirations, relating to the individual's frame of reference, with which individual i judges his satisfaction or possibilities.

Individual i's answers to the satisfaction s^i and possibilities questions p^i depend on his achievement of functionings and income, his preferences, his aspirations, his mood of the day and disturbance ε_s^i and ε_p^i:

$$\begin{aligned} s^i &= s\left(\left(f^i, y^i\right), R^i, A^i, \left(m^i, \varepsilon_s^i\right)\right). \\ p^i &= p\left(\left(f^i, y^i\right), R^i, A^i, \left(m^i, \varepsilon_p^i\right)\right). \end{aligned}$$

The marginal rates of substitution between functionings and income[9] can differ across individuals. For instance older people might prefer health more than younger people. In this model, apart from the influence of m^i and disturbance, an individual can be more satisfied/have more possibilities in three ways: via higher functionings and income achievement, by adapting his preferences and by reducing his aspirations. Two individuals with the same preferences and functionings achievement, may have a different level of satisfaction or possibilities due to differences in aspirations.

In order to compare the measures we deal with below, a number of criteria an ethically sound well-being measure could fulfill are set out. They are listed in table 1 and are written out formally in appendix B. The first criterion is an obvious criterion. A sound well-being measure should be independent of temporary influences, such as the mood of the day. The second criterion has to do with the individuals'

[9]In the satisfaction model, individual i's marginal rate of subsitution between functioning k and income is $\frac{dy^i}{df_k^i} = -\frac{\frac{\partial s^i}{\partial f_k^i}}{\frac{\partial s^i}{\partial y^i}}$.

aspirations. A comparison of the well-being of two individuals should be independent of their aspirations, as these only reflect the influence of the individuals' frame of reference with which they judge about their satisfaction or possibilities.

The third and the fourth criterion deal with dominance. A measure fulfilling the dominance criterion is increasing in all functionings and income. If two individuals are compared, the one with higher functionings or income achievement is considered better-off. We distinguish between unconditional and conditional dominance. Unconditional dominance means that the well-being measure increases in functionings and income also when preferences differ across individuals. Conditional dominance means that the well-being measure increases in functionings and income, but on the condition that preferences are the same across individuals. If a measure fulfills the unconditional dominance criterion, it also fulfills the conditional dominance criterion.

Criteria 5 and 6 deal with respect for preferences. A distinction is made between conditional and unconditional respect. A well-being measure fulfilling unconditional respect for preferences takes into account inter-individual differences in preferences also when individuals' aspirations differ. Conditional respect means that preferences are respected conditional on the fact that aspirations are the same across the compared individuals. If a measure fulfills the unconditional respect for preferences criterion, it also fulfills the conditional respect for preferences criterion.

As argued in Fleurbaey et al. (2009), there is a conflict between the unconditional respect for preferences criterion and the unconditional dominance criterion. If preferences are to be respected, unconditional dominance has to be given up, i.e. a well-being measure can not fulfill both criteria. Below, we opt to keep keep criterion 5 and so we will have to stick with the conditional dominance criterion. In fact, none of the measures used below satisfies the dominance criterion. In section 4.5.2 each of the proposed well-being measures is evaluated in terms of the criteria listed in table 1.

Table 1: Criteria for well-being measures

	Criterion
1	Independence of the mood of the day
2	Independence of aspirations
3	Unconditional dominance
4	Conditional dominance
5	Unconditional respect for preferences
6	Conditional respect for preferences

4.4 The data

The 2011 LEVO questionnaire is used, taken in Flanders, the northern part of Belgium. The sample contains 1158 usable observations[10], table 2 contains summary statistics. Apart from demographic and socio-economic information, respondents were asked questions related to their functionings and their possibilities in 10 dimensions (see appendix A) and about their satisfaction with life –'how satisfied are you with your life as a whole, on a scale from 0 to 10?'. The answer to the last possibilities question –'how are the possibilities for you, in general, on a scale from 0 (completely insufficient) to 10 (excellent)?'– is used as a measure of self-reported possibilities. Apart from family income, five dimensions of functionings[11] are distinguished from the available data: being in good health (f_1 health), being well-educated (f_2 education), having a good social life (f_3 social) and living in a pleasant environment (f_4 environment). The fifth functioning has to do with the individual's employment situation and consists of five dummies: f_5 retired, f_6 unemployed, f_7 unable to work, f_8 housewife and f_9 working. This list is in line with the list of dimensions put forward in Stiglitz et al. (2009).[12]

One remark is in place concerning the interpretation of education as a functioning. In Fleurbaey et al. (2009) and Schokkaert et al. (2011), the number of years of schooling is not a functioning, but an individual characteristic influencing preferences. In the questionnaire used for this paper, respondents are asked, on a scale from zero to ten, how well-educated they consider themselves. This comes much closer to the interpretation of a functioning in the sense of Stiglitz et al. (2009), as it measures what people manage to be or to do with their education level. It also figures in Nussbaum's list of ten dimensions of a good life. An individual who left school at an early age can consider himself well-educated if he considers his education level sufficient for the job he is doing.

[10] In total there are 1709 respondents. Students are not taken into account because of problems with the reported family income level. When missing observations are excluded, 1158 observations remain. In the empirical section below, the data are weighted to obtain a sample representative for the Flemish population according to life situation, gender and age distribution.

[11] These are the answers to the third, fourth, sixth and seventh functioning question in appendix A and the individual's employment situation.

[12] The list in Stiglitz et al. (2009) contains eight dimensions. The list of dimensions used in this paper covers six of these eight dimensions. Political voice and governance and physical and economic security are not covered, but they can be assumed equal for all respondents, as they all live in the same region. The dimension 'personal activities including work' is assumed to be covered by the five dummies relating to the individual's employment situation.

Table 2: Data description

	Mean	St.Dev	Low	High
s Self-reported satisfaction	7.36	1.38	0	10
p Self-reported possibilities	7.65	1.05	0	10
y_f Family income	3079.02	1391.62	250.00	6250
y_a Adjusted income	2032.12	958.41	250.00	6250
f_1 Health	7.50	1.59	0	10
f_2 Education	6.96	1.67	0	10
f_3 Social	7.65	1.32	0	10
f_4 Environment	7.66	1.18	0	10
f_5 Dummy retired	0.26		0	1
f_6 Dummy unemployed	0.04		0	1
f_7 Dummy unable to work	0.04		0	1
f_8 Dummy housewife	0.01		0	1
f_9 Dummy working	0.64		0	1
x_1 Dummy female	0.53		0	1
x_2 Age	48.89	16.89	18	91
x_3 Number of children	0.82	1.14	0	8
x_4 Family size	2.57	1.35	1	10
x_5 Dummy children	0.27		0	1
x_6 Dummy relationship	0.84		0	1
x_7 Dummy religious	0.74		0	1
t_1 Attitude	0.00	1.00	-3.37	2.96
t_2 Conscientious	-0.01	1.00	-3.91	2.95
t_3 Solicitous	0.04	1.00	-3.29	3.19
t_4 Expectant	0.03	1.00	-3.91	3.03
m Mood of the day	3.87	0.81	1	5

The individual characteristics refer to demographic aspects of the individual's life: gender, age, the number of children, having a relationship and being religious. There are four personality traits, numbers between -3 and +3 calculated with factor analysis based on twelve personality related questions. The four traits are attitude (t_1), conscientious (t_2), solicitous (t_3) and expectant (t_4)[13]. The respondents were also asked to state their 'mood of the day' on a scale from 1 to 5.[14]

4.5 Empirical section

This section deals with the results. In paragraph 4.5.1, the six well-being measures are proposed. In section 4.5.2 they are evaluated using the criteria from table 1. Paragraph 4.5.3 deals with the estimation of the satisfaction and the possibilities specifications. Paragraphs 4.5.4 and 4.5.5 focus on the comparison of well-being according to the measures.

[13] 'Attitude' is based on extroverted, creative, optimistic, self-confident, progressive. 'Conscientious' is based on altruistic, meticulous/dutiful, not envious. 'Solicitous' is based on worried, emotional. 'Expectant' is based on high expectations, never satisfied. The results of the factor analysis are reported in appendix C.

[14] The question is "How is your mood today?" on a scale from 1 to 5.

4.5.1 Satisfaction and possibilities measures

In this section, we translate the theoretical and empirical observations from the introduction into six well-being measures based on satisfaction and possibilities. These measures fall in three categories: income, self-reported information and equivalent income. The first two measures are family income y_f and adjusted income y_a. The third and the fourth measure are self-reported satisfaction s and self-reported possibilities p. The fifth and the sixth measure are equivalent income measures, based on respectively satisfaction and possibilities.

The satisfaction and possibilities estimations, needed for calculating equivalent income, are performed in two specifications, once without and once with preference differences, in order to facilitate comparison. In the first specification, self-reported satisfaction s^i and self-reported possibilities p^i are regressed upon the individuals' achieved functionings, personality traits, demographic characteristics and their reported mood of the day:

$$s^i = \lambda_0^s + \lambda_1^s y^i + \sum_{j=1}^{M} \nu_j^s f_j^i + \sum_{j=1}^{K} \vartheta_j^s x_j^i + \sum_{j=1}^{L} \theta_j^s t_j^i + \lambda_2^s m^i + \varepsilon_s^i, \quad (1)$$

$$p^i = \lambda_0^p + \lambda_1^p y^i + \sum_{j=1}^{M} \nu_j^p f_j^i + \sum_{j=1}^{K} \vartheta_j^p x_j^i + \sum_{j=1}^{L} \theta_j^p t_j^i + \lambda_2^p m^i + \varepsilon_p^i, \quad (2)$$

estimated with OLS.[15] Expressions (1) and (2) do not contain interactions, so here the assumption is made that all individuals have the same preferences. The expressions with interactions are

$$s^i = \alpha_0^s + \alpha_1^s y_f^i + \sum_{j=1}^{M} \beta_j^s f_j^i + \sum_{j=1}^{K} \kappa_j^s x_j^i + \sum_{j=1}^{L} \delta_j^s t_j^i + \sum_{j=1}^{L} \nu_j^s y_f^i t_j^i$$
$$+ \sum_{j=1}^{K} \tau_j^s y_f^i x_j^i + \sum_{l=1}^{M} \sum_{k=1}^{K} \gamma_{lk}^s f_l^i x_k^i + \sum_{l=1}^{M} \sum_{k=1}^{L} \eta_{lk}^s f_l^i t_k^i + \alpha_2^s m^i + \varepsilon_s^i. \quad (3)$$

[15] An ordered logit or probit specification would be more interesting from a theoretical point of view, as the data are ordinal. Ferrer-i-Carbonell and Frijters (2004) have shown that for happiness data, the results of ordinary least squares are usually very similar to the results of an ordered logit or probit.

$$p^i = \alpha_0^p + \alpha_1^p y_f^i + \sum_{j=1}^{M} \beta_j^p f_j^i + \sum_{j=1}^{K} \kappa_j^p x_j^i + \sum_{j=1}^{L} \delta_j^p t_j^i + \sum_{j=1}^{L} \nu_j^p y_f^i t_j^i + \sum_{j=1}^{K} \tau_j^p y_f^i x_j^i + \sum_{l=1}^{M}\sum_{k=1}^{K} \gamma_{lk}^p f_l^i x_k^i + \sum_{l=1}^{M}\sum_{k=1}^{L} \eta_{lk}^p f_l^i t_k^i + \alpha_2^p m^i + \varepsilon_p^i. \quad (4)$$

The coefficients with the interactions reflect differences in the marginal rates of substitution between functionings and income. The disturbance terms in all the regressions (1)-(4) measures variation in satisfaction or possibilities due to variation in unobserved explanatory variables – individual characteristics, personality traits and functionings, inter-individual differences in calibration of the answers and noise.

With coefficient estimates of expression (3), individual i's equivalent income based on satisfaction y_s^{i*} can be calculated as the amount of income that makes individual i indifferent between his actual situation and a situation with reference functionings, $\overline{f} = \left(\overline{f_1}, ..., \overline{f_M}\right) \in \mathbb{R}_+^M$:

$$y_s^{i*} = y_f^i + \frac{1}{\widehat{\alpha}_1^s + \sum_{j=1}^{L} \widehat{\nu}_j^s t_j^i + \sum_{j=1}^{K} \widehat{\tau}_j^s x_j^i} \sum_{j=1}^{M} \left(f_j^i - \overline{f_j}\right) \left(\widehat{\beta}_j^s + \sum_{k=1}^{K} \widehat{\gamma}_{jk}^s x_k^i + \sum_{k=1}^{L} \widehat{\eta}_{jk}^s t_k^i\right). \quad (5)$$

Equivalent income is calculated by 'moving' individuals on the their indifference surface in the income-functionings space. The relative value of each of the functionings depends on individual preferences.

With coefficient estimates of expression (4), individual i's equivalent income based on possibilities y_p^{i*} can be calculated in the same way:

$$y_p^{i*} = y_f^i + \frac{1}{\widehat{\alpha}_1^p + \sum_{j=1}^{L} \widehat{\nu}_j^p t_j^i + \sum_{j=1}^{K} \widehat{\tau}_j^p x_j^i} \sum_{j=1}^{M} \left(f_j^i - \overline{f_j}\right) \left(\widehat{\beta}_j^p + \sum_{k=1}^{K} \widehat{\gamma}_{jk}^p x_k^i + \sum_{k=1}^{L} \widehat{\eta}_{jk}^p t_k^i\right). \quad (6)$$

In line with Fleurbaey et al. (2009), the reference values for functionings are taken such that they represent the most favourable situation[16]. Interactions from expression (3) and (4) play a role in the measures, the direct effects of individual characteristics and personality traits are not taken into account. The equivalent income measure respects the individuals' preferences differences, but does not take into account their aspirations –the direct effects of individual characteristics and personality traits, and the disturbance term. Note that individuals with the same characteristics and personality traits are assumed to have the same preferences.

[16]For the first four functionings, this is a value of 10. For personal activities, it is the category 'working'.

4.5.2 Evaluation of the measures

In table 3 an evaluation is made of the different measures using the criteria from table 1. We do not pay too much attention to y_f and y_a, as they merely serve as a reference. All measures except s and p fulfill criteria 1 and 2. In self-reported satisfaction and possibilities, the mood of the day and aspirations play a role. Equivalent income measures y_s^* and y_p^* correct for aspirations explicitly, the two income based concepts do not depend on aspirations at all as they are not based on subjective information.

None of the proposed measures fulfills the unconditional dominance criterion. The two income concepts do not depend on the achievement of other functionings and satisfaction and possibilities are sensitive to aspirations, so an individual with higher functionings or income achievement might well have a lower score on s or p. Equivalent income does not fulfill criterion 3 either, but it fulfills the conditional dominance criterion 4. If preferences are the same, an individual with higher functionings and income achievement will be judged better off. None of the other measures fulfills the conditional dominance criterion.

Finally we deal with the respect for preferences criteria 5 and 6. Income obviously fulfills neither of the criteria, as preferences differences do not play a role at all. Self-reported satisfaction and self-reported possibilities only satisfy the conditional respect for preferences criterion. Equivalent income fulfills both criteria, as aspirations are corrected for. Note the incompatibility between unconditional respect for preferences and unconditional dominance.

Table 3: Criteria for well-being measures

	Criterion	y_f	y_a	s	p	y_s^*	y_p^*
1	Independence of the mood of the day	yes	yes	no	no	yes	yes
2	Independence of aspirations	yes	yes	no	no	yes	yes
3	Unconditional dominance	no	no	no	no	no	no
4	Conditional dominance	no	no	no	no	yes	yes
5	Unconditional respect for preferences	no	no	no	no	yes	yes
6	Conditional respect for preferences	no	no	yes	yes	yes	yes

Both y_s^* and y_p^* are interesting candidates for a well-being measure, they both satisfy five of the six criteria. Given the incompatibility, this is the maximum attainable. Below we investigate how sensitive both measures are empirically for differential functionings and income achievement.

4.5.3 Estimation results

The first two colums of table 4 contain the results of expression (1) with family income y_f and adjusted income y_a. The third and the fourth column contain the estimation results of expression (2), again with y_f and y_a. The two right-most columns contain the results of expressions (3) and (4), with interactions. The reference category in the estimations is a working unreligious single man without children. Note that in the two right-most columns, y_f is taken as income measure. Family composition is measured by having a relationship and the dummy for having children. Whether income has a linear or a non linear effect is an empirical matter. Here, the linear specification has more explanatory power.

Table 4: Satisfaction and opportunities estimation results

Dependent variable	s	s	p	p	s	p
y_f	0.084***		0.083***		0.086***	0.084***
y_a		0.059		0.086***		
f_1 Health	0.112***	0.111***	0.122***	0.121***	0.116***	-0.059
f_2 Education	0.067***	0.072***	0.122***	0.124***	0.192***	0.226***
f_3 Social	0.138***	0.139***	0.163***	0.164***	0.131***	0.168***
f_4 Environment	0.245***	0.246***	0.182***	0.183***	-0.092	0.188***
f_5 Retired	-0.242	-0.283*	0.065	0.298	-0.244	0.046
f_6 unemployed	-0.089	-0.128	-0.021	-0.047	-0.138	-0.072
f_7 unable to work	-0.562***	-0.586***	-0.029	-0.051	-0.540***	0.063
f_8 housewife	-0.067	-0.091	0.007	-0.010	-0.021	0.011
x_1 Dummy female	0.020	0.023	-0.028	-0.029	-0.013	-0.047
x_2 Age	-0.032**	-0.026*	-0.008	-0.002	-0.061***	-0.020
$x_2 * x_2$ /1000	0.386***	0.329**	0.090	0.030	0.335**	0.101
x_5 Dummy children	0.228**	0.284***	0.000	0.067	0.223**	0.007
x_6 Dummy relationship	0.263**	0.314***	0.134*	0.187**	0.261**	0.118
x_7 Dummy religious	0.166*	0.163*	0.034	0.035	0.157*	0.047
t_1 Attitude	0.115***	0.115***	0.020	0.022	0.122***	0.016
t_2 Conscientious	0.079**	0.081**	-0.002	0.001	0.430**	-0.007
t_3 Solicitous	0.021	0.013	0.006	0.001	0.003	0.008
t_4 Expectant	-0.005	0.004	0.021	0.027	-0.002	0.027
f_2 * age					-0.002*	-0.002***
f_3 * t_2					-0.047**	
f_4 * age					0.007***	
f_6 * t_3					0.310*	
f_8 * t_4					-0.329*	
f_1 * age						0.003***
f_6 * t_1						-0.185*
f_7 * t_1						0.498***
m Mood of the day	0.287***	0.286***	0.133***	0.132***	0.276***	0.128***
Constant	1.964***	1.879***	2.486***	2.324***	3.626***	3.070***
Adjusted R^2	0.32	0.32	0.40	0.40	0.33	0.42

Note: Estimation results of expressions (1) and (2) are shown in the first four columns. The results of the estimation of expressions (3) and (4) can be found in the two right-most columns. The dependent variables are self-reported satisfaction and self-reported possibilities. Significance at the 1%, 5% and 10% level are denoted with ***, ** and * respectively.

Now we focus on some differences between the satisfaction estimations and the possibilities estimations in the four left-most columns, the estimations without preference differences. First of all, note that, whereas family income is significant in both cases, adjusted income is only significant in the possibilities regression. This remains true also when family composition variables are left out of the specification –not shown in the table. This is a surprising result, adjusted income comes much closer to the amount of wealth per member of the family, apparently this does not bring satisfaction, but it brings possibilities. The result might be due to a prestige effect. A higher family income brings prestige –living in a bigger house, driving a bigger car– and thus more satisfaction, but if an income concept is taken that comes closer to the disposable income per family member, the effect on satisfaction disappears.

One important difference between the two types of specifications is the relative contribution to the explained variance of each of the groups of variables –functionings, individual characteristics, personality traits and mood. In appendix D, the results of the variance decomposition of the estimation of expressions (1) and (2) are provided. In the satisfaction regression, functionings and family income contribute to around 61% of the explained variance, whereas for the possibilities regressions, these variables account for 84% of the explained variance. The remaining variance in both cases is mostly explained by mood of the day, be it more strongly in the case of satisfaction than in the case of possibilities. Personality traits do not explain self-reported possibilities at all. This shows that self-reported possibilities depend more on functionings achievement, as in Van Ootegem and Verhofstadt (2012). As such the result suggests that self-reported possibilities are a more objective judgment about the individuals' lives.

There are also some differences in the estimated coefficients of some of the functionings. Education contributes more to possibilities than to satisfaction and living in a pleasant environment brings more satisfaction than possibilities. This can be seen as evidence that the respondents perceive possibilities as something different than satisfaction. Education increases an individual's possibilities, as e.g. job market opportunities may depend on education. Note that education is measured as the extent to which individuals consider themselves well-educated, not in the classical way as the number of years of schooling. Of the functioning 'personal activities' –functionings 5 to 9, those unable to work are less satisfied than the working, but none of these variables has a significant impact on possibilities.

More important for our purposes are the effects of individual characteristics and personality traits. The latter only play a role in the satisfaction regression, so we could say that satisfaction is more dependent on the mental state of the individual than possibilities, in line with Van Ootegem and Verhofstadt (2012 and 2013). Individual characteristics have more effect on satisfaction than on possibilities, e.g. having children and being religious increase satisfaction but do not influence possibilities. The same holds for age, where there is a U-shaped relationship in the satisfaction regression, but no effect on possibilities. Only having a relationship brings both satisfaction and possibilities.

The mood of the day has a strong effect on both satisfaction and possibilities, though its coefficient is twice as large and more significant in the former case than in the latter case. All this is evidence that the respondents distinguish possibilities from satisfaction. The results concerning satisfaction are generally in line with the existing satisfaction literature (see e.g. Dolan et al. (2006)).

Now we have a closer look at the results in the two right-most columns of table 4, with interactions. Family income is used in the regression, as the coefficient with adjusted income is not significant in the satisfaction regression. The direct effects of x and t in the regressions are interpreted as differences in aspirations. None of these variables has a significant direct influence on the possibilities measure, but they do influence satisfaction. This means that, empirically, aspirations do not play a statistically significant role in the possibilities measure.

The interactions are interpreted as differences in preferences associated with individual characteristics and personality traits. No interactions with income and health were found to be significant in the satisfaction regression, and no interactions with income and the functioning social relations were found to be significant in the possibilities regression. The interpretation is that there are no inter-individual differences in preferences for these functionings.

Now we deal with funtionings achievement. Family income and all functionings have a significantly positive effect on satisfaction for the reference individual, except the functioning ‘living in a pleasant environment’. This functioning only enters in interaction with age, the older people get, the more this functioning contributes to satisfaction[17]. Education is less preferred by older individuals[18]. There are three interactions with personality traits: more conscientious people value the social functioning more, the unemployed are less satisfied when they are unsolicitous and housewives are less satisfied when they have high expectations.

In terms of possibilities, the functioning health does not have a significant effect for the reference individual. It only enters in interaction with age, older people transform health into more possibilities.

[17]Note that the youngest individual in the sample is 18. The interaction coefficient is 0.007, so a unit of functioning f_4 yields 0.007*18=0.126 units of satisfaction. The older people get, the higher this number is.

[18]The direct effect of a unit of f_2 is 0.192. The reference individual is aged 0. For an individual of 18, the impact on satisfaction of an extra unit of f_2 is 0.192-18*0.002=0.156. As individuals get older, this impact decreases.

Education yields less possibilities the older people get.[19] The unemployed experience less possibilities when they have a positive attitude and the unable to work achieve more possibilities when they have a positive attitude.

The differences between the statistically significant interactions in the two columns on the right hand side might be due to two things. First, we do not measure individual preferences, but group preferences[20]. To the extent that our definition of the groups does not capture sufficiently the preferences of the individuals in them, different interactions might appear significant in the two regressions. The second reason has to do with data imperfections, people might make mistakes when answering the questions.

4.5.4 Comparing lives

Now we have six measures of well-being: the references of family income y_f and adjusted income y_a, one measure proposed in the literature: self-reported satisfaction s, a measure proposed by Van Ootegem and Verhofstadt (2013): self-reported possibilities p, and equivalent income y_s^* and y_p^*. First we have a look at the Spearman rank correlations between these, provided in table 5. The correlations between income and the other measures are relatively low, which points to the fact that a high income is no guarantee for a high achievement of other functionings. If the measure of individual well-being is solely based on income, other relevant aspects of life are clearly omitted. The low correlations between income and self-reported satisfaction are striking and point to the fact that ranking individuals based on satisfaction is something different than ranking them based on income. Both s and p correlate more with y_s^* and y_p^*.

The correlation between s and p is 0.487, which is considerable. It is interesting to not that the correlation between fitted values of expressions (3) and (4) is around 23% –not shown in the table. This means that there is correlation between the residuals of the estimations. This can be related to the above discussion of the calibration problem. The result suggests that there might be an individual fixed effect in the judgments of satisfaction and possibilities. An individual uses the same type of calibration for deciding the answer to the satisfaction and to the possibilities question. As expected, y_s^* and y_p^* correlate highly. Both measures are explicitly related to functionings achievement, in contrast to e.g. family income

[19] At the age of 18, a unit of f_1 yields 0.054 units of possibilities and a unit of f_2 yields 0.190 units of possibilities.

[20] Groups are based on personality traits and individual characteristics.

or adjusted income. This explains the high correlation between them, as the only difference is the fact that functionings are weighted in a different way.

Table 5: Spearman rank correlations between the indicators

	y_f	y_a	s	p	y_s^*	y_p^*
y_f	1					
y_a	0.833	1				
s	0.178	0.104	1			
p	0.206	0.175	0.487	1		
y_s^*	0.358	0.331	0.474	0.596	1	
y_p^*	0.396	0.370	0.454	0.616	0.916	1

Note: All correlations are significant at the 1% level. Spearman rank order correlations are calculated between family income y_f, adjusted income y_a (family income divided by the square root of family size), self-reported satisfaction s with life, self-possibilities p, equivalent income based on satisfaction y_s^* (based on expression (5)) and equivalent income based on possibilities y_p^* (based on expression (6)).

In order to facilitate more specific inter-individual comparisons and comparisons across the measures, average standardised scores are calculated[21]. Table 6 tabulates the average standardised scores of each of the six measures, for individuals with high and low values for each of the functionings, individual characteristics and the personality traits. High and low values for the functionings are chosen such that each line in the table contains (at least) 15% of the respondents. For the dummy variables, high and low values are naturally equal to 1 and 0. We have to be careful when interpreting the numbers in the table, as they only allow for one-dimensional comparisons between measures. If the difference between high and low is not significant, the box is left empty. The largest difference is underlined.

The first observation from the table is that the two measures on the right hand side are more responsive to differences in functionings achievement than s and p, which are in turn more responsive than income. This is due to the fact that y_s^* and y_p^* are constructed in order to take functionings achievement into consideration. For health, education, the social functioning and being unemployed, the difference is strongest in terms of y_p^*; for the environmental functioning and being unable to work, the difference is strongest in terms of y_s^*. Note that the numerical differences between these columns are often small. Though s and p suffer from the influence of aspirations, the mood of the day and disturbance, they are generally in line with the individuals' functionings achievement. Self-reported possibilities p appear to be more responsive to functionings differences than s, so if a self-reported measure is to be used as well-being measure, then it is better to take possibilities than satisfaction.

In the two left-most columns, it can be seen that the income measures do not show a lot of varia-

[21] This is, for each measure, the value minus the average divided by the standard deviation.

tion for high and low values of the first four functionings, except for high and low values of education and the functioning personal activities. The former might be due to the connection between education level and the type of job people have. The latter is due to the connection between income and having a job. Retired people have clearly a lower income level compared to the other categories. Though, when multidimensional well-being is the issue, focusing on income alone is clearly not sufficient.

Table 6: Average standardised scores of the well-being measures for high and low scores of functionings, individual characteristics and personality traits

		y_f	y_a	s	p	y_s^*	y_p^*
y_f Family income	h	1.729	1.355	0.294	0.296	0.578	0.645
	l	-1.341	-1.078	-0.202	-0.340	-0.509	-0.541
y_a Adjusted income	h	1.330	1.825	0.108	0.122	0.457	0.494
	l	-1.209	-1.165	-0.214	-0.382	-0.557	-0.584
f_1 Health	h	0.213	0.227	0.380	0.510	0.769	0.872
	l	-0.292	-0.225	-0.613	-0.682	-1.095	-1.254
f_2 Education	h	0.497	0.521	0.424	0.725	0.900	1.060
	l	-0.499	-0.437	-0.475	-0.660	-0.950	-1.152
f_3 Social	h	0.068	0.191	0.470	0.605	0.866	0.871
	l	-0.307	-0.309	-0.589	-0.843	-1.140	-1.176
f_4 Enviroment	h	-0.029	-0.031	0.547	0.663	1.084	0.916
	l	-0.232	-0.148	-0.670	-0.753	-1.259	-1.085
f_5 Dummy retired	1	-0.717	-0.498	-0.065	-0.099	-0.370	-0.384
f_6 Dummy unemployed	1	-0.544	-0.350	-0.481	-0.521	-0.427	-0.452
f_7 Dummy unable to work	1	-0.030	-0.021	-0.738	-0.506	-1.203	-0.945
f_8 Dummy housewife	1	-0.260	-0.153	-0.259	0.273	-0.035	-0.150
f_9 Dummy working	1	0.339	0.233	0.111	0.102	0.258	0.251
x_1 Dummy female	0	0.095	0.091				
	1	-0.084	-0.081				
x_2 Age	≥ 70	-0.882	-0.591		-0.171	-0.508	-0.554
	≤ 27	0.023	0.765		0.165	0.483	0.424
x_5 Dummy children	1	0.510	-0.137	0.133		0.143	0.160
	0	-0.184	0.049	-0.048		-0.052	-0.058
x_6 Dummy relationship	1	0.092	-0.034	0.072	0.048	0.047	0.042
	0	-0.495	0.181	-0.387	-0.259	-0.253	-0.228
x_7 Dummy religious	1	-0.065	-0.098	0.036			-0.029
	0	0.189	0.283	-0.103			0.085
t_1 Attitude	h	0.111	0.033	0.317	0.318	0.386	0.460
	l	-0.190	-0.137	-0.373	-0.316	-0.461	-0.506
t_2 Conscientious	h	-0.155	-0.195	0.231	0.142	0.318	0.083
	l	-0.003	0.199	-0.311	-0.198	-0.384	-0.190
t_3 Solicitous	h	-0.253	-0.269		-0.179	-0.131	-0.242
	l	0.204	0.179		0.106	0.127	0.145
t_4 Expectant	h	0.361	0.277		-0.004	0.027	0.055
	l	-0.286	-0.059		-0.170	-0.190	-0.155

Note: Adjusted income is family income divided by the square root of family size. Equivalent income y_s^* is based on expression (5), y_p^* is based on expression (6). The numbers in the table provide the average standardised scores of each of the measures (columns) for individuals belonging to the 15% highest or lowest values for each of the variables in the rows. If the difference between the groups is not significant, the box is left empty.

As regards the individual characteristics, in the second block of the table, the largest differences appear in the two left-most columns. Only for age, the equivalent income measures show some variation. This is due to the interactions between functionings and age in table 4. The third block of the table contains the differences in the measures for different personality traits. Both equivalent income and the possibilities measure are quite responsive for the first two personality traits, which is due to the interactions from table 4. Note that the numbers in the three right-most columns almost all have the same sign. This might be evidence that an individual's personality has a real influence on his well-being and the things he reaches in life.

4.5.5 Who are the rich and the poor?

We are interested in a measure that is useful for policy recommendations, for instance to determine who is to be considered poor. In this section we investigate the profile of the 'poor' and the 'rich' for each of the measures, with an approach put forward by de Barros et al. (2009). We investigate which type of individuals are selected if the 15% worst-off and the 15% best-off according to the six measures are taken. This is shown in table 7. Each column of the tables contains 15% of the sample with the highest and the lowest values for each of the six measures.

Each cell in the table contains the average value for each of the functionings and individual characteristics of the 15% best-off and worst-off, divided by the mean value –reported in table 2. A number higher (lower) than 1 indicates that a value is higher (lower) than average in terms of functionings achievements, and that a type of individuals is overrepresented (underrepresented) for the individual characteristics. The values for the personality traits are not divided by their mean, as this is equal to zero. In terms of functionings achievement, y_s^* and y_p^* provide the most pronounced picture, as the differences in functionings achievement between high and low values of these measures are highest. As above, self-reported satisfaction and possibilities perform better than the two income based measures. Both income measures do not differentiate considerably in terms of functionings achievement, except for the functioning 'personal activities' $f_5 - f_9$. Note that also here p performs better than s in terms of differentiating rich and poor in terms of functionings achievement.

The individual characteristics provide an interesting picture as well. Again, as in table 6, the differences are biggest in the case of income. Women figure more in the low income categories in table 7, though in terms of the other measures they are not ranked as worse-off. The average age in the low income categories is considerably higher than in the high income categories. This is not surprising, as pensions are generally lower than income. This difference also appears in the case of the equivalent income measures, though the difference in terms of s and p is smaller. Apparently income decreases with age, but this does not hold for satisfaction or possibilities.

The unemployed are considered worse-off according to all measures. In terms of the other personal

Table 7: Rich and poor according to each of the measures

	y_f		y_a		s		p		y_s^*		y_p^*	
	l	h	l	h	l	h	l	h	l	h	l	h
y_f	0.394	1.781	0.454	1.601	0.836	1.042	0.824	1.148	0.762	1.212	0.736	1.269
y_a	0.492	1.639	0.451	1.861	0.916	1.017	0.864	1.101	0.775	1.223	0.767	1.272
f_1	0.941	1.049	0.927	1.031	0.863	1.084	0.843	1.114	0.765	1.183	0.739	1.185
f_2	0.910	1.114	0.900	1.102	0.882	1.078	0.830	1.152	0.779	1.192	0.736	1.237
f_3	0.974	1.030	0.958	1.033	0.903	1.090	0.859	1.116	0.815	1.157	0.796	1.166
f_4	0.980	1.026	0.975	1.009	0.887	1.073	0.878	1.102	0.801	1.175	0.828	1.144
f_5	2.231	0.127	1.950	0.362	1.308	1.146	1.262	0.904	1.658	0.596	1.635	0.573
f_6	1.975	0.425	2.175	0.875	2.150	0.575	2.400	0.600	1.875	0.575	2.000	0.425
f_7	0.175	0.700	0.725	1.025	2.450	0.225	1.950	0.725	3.450	0.000	3.025	0.725
f_8	1.800	0.600	2.900	1.800	2.000	1.900	1.800	2.900	1.700	1.700	1.100	0.600
f_9	0.492	1.433	0.544	1.269	0.711	1.016	0.748	1.066	0.530	1.258	0.566	1.248
x_1	1.089	0.875	1.136	0.866	1.011	1.079	0.964	0.966	0.975	1.062	1.008	1.085
x_2	1.221	0.883	1.196	0.807	1.064	1.039	1.080	0.987	1.182	0.869	1.166	0.879
x_5	0.084	0.587	0.263	0.172	0.224	0.294	0.271	0.337	0.245	0.322	0.217	0.365
x_6	0.689	1.073	0.869	0.848	0.864	1.074	0.906	1.093	0.937	1.046	0.931	1.046
x_7	1.074	0.911	1.089	0.850	0.954	1.059	0.984	0.993	1.026	1.032	1.095	0.970
t_1	-0.228	0.189	-0.265	-0.013	-0.360	0.355	-0.401	0.422	-0.556	0.461	-0.592	0.434
t_2	0.014	-0.015	-0.024	-0.286	-0.258	0.167	-0.182	0.286	-0.356	0.359	-0.126	0.240
t_3	0.085	-0.279	0.181	-0.231	0.144	-0.054	0.177	-0.055	0.149	-0.031	0.267	-0.069
t_4	-0.255	0.386	-0.244	0.178	-0.032	0.033	-0.077	0.141	0.018	0.109	-0.025	0.176

Note: Family income is y_f, adjusted income y_a is family income divided by the square root of family size. Self-reported satisfaction with life is s and self-reported possibilities are p. The equivalent income measures y_s^* and y_p^* are based on expressions (5) and (6) respectively. Functioning f_1 is health, f_2 is the functioning education, f_3 is the social functioning and f_4 is the functioning living in a pleasant environment. Functionings 5-9 are respectively the dummies for retired, unemployed, unable to work, housewife and working. The individual characteristics x_1 is a dummy for female, x_2 is age, x_5 is the dummy for children, x_6 is the dummy for having a relationship and x_7 is the dummy for religious. The personality trait variables are t_1 attitude, t_2 conscientious, t_3 solicitous and t_4 expectant. The numbers in the tables provide the averages of each of the row variables for individuals in the high or low ranges of the column variables.

activities, the judgment depends on the type of measure taken. According to all measures except y_p^*, the retired are categorised as worse-off and the working are considered as better-off. Housewives are overrepresented in both the high- and the low- categories. The retired and the working do not differ in terms of y_p^*, though their income or satisfaction is lower. The unable to work are especially badly off in terms of the four measures on the right-hand side, not in terms of income. Note that none of the unable to work are categorised in the high-y_s^* category.

Individuals without children or a relationship figure more in the low y_f category, but after correcting for family size, this is not the case anymore. Those without a relationship are overrepresented both in the low and high-y_a category. This is because, due to the correction for family size, singles end up in the high-y_a category and individuals in large families in the low-y_a category. Note that those individuals without a relationship are worse off according to all measures. Having children does not affect the other well-being measures. Finally, the results concerning the personality traits, in the bottom four rows of table 7, show that the satisfied, those with high y_s^* and those with high y_p^* have a more positive attitude and are more conscientious.

The analysis makes clear that evaluating individuals in terms of y_p^* is a legitimate way to evaluate well-being. It fulfills the same formal criteria as y_s^*, and performs empirically as well in deciding about who is better or worse off. When well-being is judged in terms of possibilities, different individuals are considered as poor. Information on possibilities might complement judgements based on other measures such as equivalent income.

4.6 Conclusions

In this paper we hypothesized that another overarching evaluation question, self-reported possibilities, could overcome some of the problems with self-reported satisfaction information. Self-reported satisfaction information suffers from two problems: its dependence on aspirations and its dependence on affects. The aim was to investigate consequences of this idea empirically using the dimensions of functionings proposed by Stiglitz et al. (2009). Two possibilities measures were evaluated: self-reported possibilities and equivalent income based on self-reported possibilities. These measures were compared with four other well-being measures used in the literature: family income, income adjusted for family size, self-reported satisfaction and equivalent income based on satisfaction. This comparison is based on a number of formal criteria. It is shown that equivalent income fulfills some interesting formal criteria for a well-being measure that the other measures do not fulfill.

We argue that there is a conceptual difference between self-reported satisfaction with life and self-reported possibilities. The effects of individual characteristics and personality traits are to be given a different interpretation. They serve as determinants of preferences. We side with those who argue that inter-individual differences in preferences should be taken into account in a good measure of well-being, if these are not flawed. A well-being measure that does not respect these inter-individual differences is paternalistic, which is considered less interesting from a normative point of view, as it might go against individuals' own point of view about what matters in their lives.

In the empirical section, the differences between satisfaction and possibilities are investigated. It is shown that education provides more possibilities, while living in a pleasant environment brings more satisfaction. Further, compared to self-reported satisfaction, self-reported possibilities depend less on individual characteristics and not at all on personality traits. Especially the latter observation is interesting for our purposes, as it shows that self-reported possibilities are perceived as something more objective than satisfaction with life. Self-reported possibilities are more responsive to differences in functionings achievement than self-reported satisfaction. This is bad news for those who see satisfaction with life as a good way to evaluate well-being.

The equivalent income measures respond more to differences in functionings achievement than the four other measures. Equivalent income based on possibilities performs slightly better than equivalent income based on satisfaction in differentiating between those with higher and lower functionings achievement. The possibilities poor in our sample are predominantly the unemployed and those unable to work, and individuals without a relationship, whereas in terms of the other measures, the retired are also considered as badly off. Apparently these individuals are not possibilities poor, though they are income poor or equivalent income poor. We conclude that equivalent income based on possibilities might well serve as an interesting measure for policy purposes.

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Appendix A - Questionnaire

Possibilities: How are the possibilities for you... (on a scale from 0 (completely insufficient) to 10 (excellent))

1. to find happiness in your life?
2. that you have to reach achievements in your life?
3. that you have to live a healthy life?
4. with respect to education and training that you have access to?
5. to achieve enough income?
6. to have a satisfying social life?
7. to be in pleasant environments?
8. that you have to live according to your personal opinion and way of thinking?
9. to decide the direction of your life in your situation?
10. to decide the direction of your life in your relationship?
11. in general?

Functionings: What have you reached in your life... (on a scale from 0 (completely disagree) to 10 (completely agree))

1. in general I lead a happy life.
2. given my age, I have reached many of my goals.
3. I consider myself to be in good health.
4. I consider myself well-educated.
5. my (family) income is sufficient to live a good life.
6. I have a good social life (friends, clubs,...)
7. I live and spend my time in pleasant environments (life, work, nature,...)
8. I respect my personal vision when taking decisions.
9. I am satisfied with my current life situation (studying, working, retired,...)
10. I am satisfied with my relationship.

Appendix B: Criteria for well-being measures

In this appendix the criteria from section 4.2 are written formally. Denote a measure of individual i's well-being by $W\left(f^i, y^i, R^i, A^i, m^i\right)$. We introduce the following notation: $m^i \in \mathcal{M} \subseteq \mathbb{R}_+$, where $\mathcal{M}$ is the set of all possible levels of the mood of the day; $A^i \in \mathcal{A} \subseteq \mathbb{R}_+$, where $\mathcal{A}$ is the set of all possible levels of aspirations and $R^i \in \mathcal{R}$, where $\mathcal{R}$ is the set of all possible preferences.

The first feature of a good well-being measure is that it does not depend on temporary influences such as the mood of the day.

Criterion 1: Independence of the mood of the day:

$$\text{If } \left(f^i, y^i\right) R^i \left(f^{i\prime}, y^{i\prime}\right), \text{ then it must be that for all } m \in \mathcal{M}:$$
$$W\left(f^i, y^i, R^i, A^i, m\right) \geq W\left(f^{i\prime}, y^{i\prime}, R^i, A^i, m\right).$$

In the following criteria, we leave the mood of the day out of consideration. The second criterion deals with aspirations. A sound well-being measure is to be independent of the individuals' frame of reference, thus it should not depend on their aspirations.

Criterion 2: Independence of aspirations:

$$\text{If } \left(f^i, y^i\right) R^i \left(f^{i\prime}, y^{i\prime}\right), \text{ then it must be that for all } A \in \mathcal{A} \text{ and for all } m \in \mathcal{M}:$$
$$W\left(f^i, y^i, R^i, A, m\right) \geq W\left(f^{i\prime}, y^{i\prime}, R^i, A, m\right).$$

Criteria 3 and 4 deal with dominance. A well-being measure satifies dominance if it is increasing in functionings and income. We distinguish between conditional and unconditional dominance. Unconditional dominance means that dominance holds for individuals with different preferences; conditional dominance means that dominance holds conditional on the fact that the individuals have the same preferences. Obviously, if a measure satisfies unconditional dominance, it automatically satisfies conditional dominance.

Criterion 3, unconditional dominance, can be written as

$$\text{If } \left(f^i, y^i\right) \geq \left(f^{i\prime}, y^{i\prime}\right) \text{, then it must be that}$$
$$\text{for all } A \in \mathcal{A}\text{, for all } R \in \mathcal{R} \text{ and for all } m \in \mathcal{M} :$$
$$W\left(f^i, y^i, R, A, m\right) \geq W\left(f^{i\prime}, y^{i\prime}, R, A, m\right).$$

Criterion 4, conditional dominance, can be written as

$$\text{If } \left(f^i, y^i\right) \geq \left(f^{i\prime}, y^{i\prime}\right) \text{, then it must be that for all } A \in \mathcal{A} \text{ and for all } m \in \mathcal{M} :$$
$$W\left(f^i, y^i, R^i, A, m\right) \geq W\left(f^{i\prime}, y^{i\prime}, R^i, A, m\right).$$

Criteria 5 and 6 deal with respect for preferences differences. We differentiate between conditional and unconditional respect for preferences (see Schokkaert et al. (2011)). Conditional respect for preferences means that if two individuals are compared, their preferences are respected on the condition that their aspirations are the same. It allows inter-individual comparisons of individuals with the same aspirations. Unconditional respect means that two individuals can be compared also if their aspirations differ. Obviously, if the unconditional respect criterion is fulfilled, the conditional respect criterion is fulfilled.

Criterion 5 unconditional respect for preferences

$$\text{If } \left(f^i, y^i\right) R^i \left(f^{i\prime}, y^{i\prime}\right) \text{, then it must be that, for all } m \in \mathcal{M} :$$
$$W\left(f^i, y^i, R^i, A^i, m\right) \geq W\left(f^{i\prime}, y^{i\prime}, R^i, A^{i\prime}, m\right).$$

Criterion 6 conditional respect for preferences

$$\text{If } \left(f^i, y^i\right) R^i \left(f^{i\prime}, y^{i\prime}\right) \text{, then it must be that, for all } m \in \mathcal{M} :$$
$$W\left(f^i, y^i, R^i, A^i, m\right) \geq W\left(f^{i\prime}, y^{i\prime}, R^i, A^i, m\right).$$

Appendix C - Factor analysis

Respondents were asked to score themselves on a numeric 7-point scale between 3/2/1/0/1/2/3 on 12 personality related opposites: introverted-extroverted, selfish-altruistic, not meticulous/dutiful-very meticulous/dutiful, not worrying-worrying a lot, easily satisfied-never satisfied, not creative-very creative, pessimistic-optimistic, little self confidence-confident, rational-emotional, conservative-progressive, not envious-envious and low expectations-high expectations. Using principal components anaylysis, the twelve personality related variables were reduced to four factors (the t variables in the paper). The number of factors is not determined in advance, but those factors with eigenvalues higher than 1 have been kept. These four factors explain together 56% of the the variance in the 12 personality related variables.

The table below contains the rotated component matrix

Table C1: Rotated component matrix

	t_1 Attitude	t_2 Conscientious	t_3 Solicitous	t_4 Expectant
Extroverted	0.591	0.176	0.162	-0.065
Altruistic	0.177	0.644	0.340	-0.067
Meticulous	0.079	0.624	0.151	0.537
Worrying a lot	-0.178	0.144	0.650	0.456
Never satisfied	-0.070	-0.285	0.017	0.703
Very creative	0.524	-0.024	0.218	0.051
Optimistic	0.705	0.316	-0.155	-0.132
Self confident	0.668	0.131	-0.361	0.049
Emotional	0.247	0.026	0.777	-0.118
Progressive	0.630	-0.215	0.181	0.099
Envious	0.007	-0.679	0.163	0.231
High expectations	0.506	0.015	-0.116	0.546

'Attitude' t_1 is based on extroverted, creative, optimistic, self-confident, progressive. 'Conscientious' t_2 is based on altruistic, meticulous/dutiful, not envious. 'Solicitous' t_3 is based on worried, emotional. 'Expectant' t_4 is based on high expectations, never satisfied.

Appendix D - Variance decomposition

In order to investigate the joint contribution of functionings/income, individual characteristics, personality traits and mood, a variance decomposition analysis is performed for the estimations of the first and the third columns of table 4. Table D1 provides the percentages contributed by each group of variables in the explained variance of satisfaction and possibilities respectively.

Table D1: Variance decomposition of expression (1)

	s	p
Family income and functionings	0.610	0.842
Individual characteristics	0.062	0.008
Personality traits	0.029	0.002
Mood	0.081	0.025
Covariance y_f / f and x	-0.051	0.001
Covariance y_f / f and t	0.078	0.019
Covariance y_f / f and mood	0.140	0.097
Covariance x and t	0.006	0.000
Covariance x and mood	0.016	0.004
Covariance t and mood	0.028	0.002